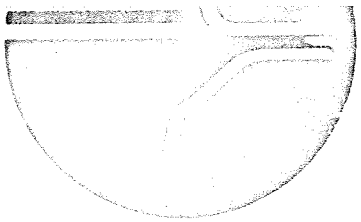
DE-SMS-II-018

LIFE SCIENCES SPACELAB MISSION SIMULATION II

Experiments and Operations Requirements



National Aeronautics and Space Administration

LYNDON B. JOHNSON SPACE CENTER

Houston, Texas

November, 1975

DE-SMS-II-018

SPACELAB MISSION SIMULATION-II (SMS-II)
EXPERIMENTS AND OPERATIONS REQUIREMENTS

Approved by _____
E. V. LaFevers, Ph. D., SMS-II Documentation Manager

Approved by _____
W. C. Alexander, Ph. D., SMS-II Science Manager

Approved by _____
W. J. Huffstetler, Chairman, SMS-II MMB

Approved by _____
R. S. Johnston, Director of Life Sciences

REVISIONS

REV. SYM	DESCRIPTION	DATE	APPROVED
A	The attached pages contain corrections and additions to Life Sciences SMS-II Experiments and Operations Requirements (DE-SMS-II-018). Corrected information is indicated by a black vertical line in the margin and opposite the correction. Please remove and discard the following pages of your manual and replace each page by the corrected copy attached. Table of Contents pp. *v* and *vi*; Acronyms p. *xi*. Section 4.12, pp. 99 through 108. Section 5.8, pp. 175 and 176. Section 5.8A, pp. 178A through 178D, is an addition to Section 5.8 and should be placed between pp. 178 and 179. Section 5.9A, pp. 181A through 181D, is in addition to Section 5.9 and should be placed between pp. 180 and 183. *NOTE:* pp. 181 and 182 are being reprinted to accommodate this addition. Section 5.15, pp. 196 through 198 is to be placed following p. 195. Please place these instructions in the front of the book between pp. *ii* and *iii*.	1/26/76	wg Jaffe 1-27-76

Page intentionally left blank

TABLE OF CONTENTS

TABLE OF CONTENTS (concluded)

LIST OF FIGURES

Page intentionally left blank

ACRONYMS, ABBREVIATIONS AND DEFINITIONS

A/D	Analog-to-Digital
A/G	Air-to-Ground
AOS	Acquisition of Signal
APEAS	Automated Potentiometric Electrolyte Analysis System
BFVM	Blood Flow/Volume Measuring
BMMD	Body Mass Measurement Device
BMS	Biowaste Monitoring System
BOP	Baseline Operations Plan
BP	Blood Pressure
BPMS	Blood Pressure Measuring System
CAMAC	Computer Automated Monitor and Acquisition Control
CCB	Change Control Board
CO	Cardiac Output
CORE	Common Operational Research Equipment
CPU	Central Processing Unit
CRL	Cosmic Ray Laboratory
DE	Bioengineering System Division
DSAD	Data Systems and Analysis Directorate
DTO	Detailed Test Objective
DTU	Development Test Unit
ECG	Electrocardiogram
EMI	Electromagnetic Interference
EMG	Electromyogram
ENG	Electronystagmography
ER(s)	Experiment Requirement(s)
ETV	Engineering TV
EU	Electronic Unit
FDF	Flight Data File
FM	Frequency Modulation
FTU	Fluid Transport Unit
GDP	Generalized Document Processor
G.m.t.	Greenwich Mean Time

HAL	Houston Assembly Language
HR	Heart Rate
ICS	Intercostal Space
I/O	Input-Output
IMSS	In-flight Medical Support System
IRIG	Interrange Instrumentation Group
JSC	Johnson Space Center
Kcal	Kilocalorie
LOS	Loss of Signal
LSD	Life Sciences Directorate
LSPF	Life Sciences Payloads Facility
ME	Muscle Efficiency
MODEM	Modulator/Demodulator
MOPAC	Mobile Power and Control
MPAD	Mission Planning and Analysis Division
MS	Mission Specialist; Mass Spectrometer
MSS	Multispectral Scanner
MVC	Maximum Voluntary Contraction
MUON	μ meson
MWPC	Multiwire Proportional Counter
NIM-CAMAC	Nuclear Instrument Modules - Computer Automated Modular Acquisition and Control
NRZ	Non Return Zero (Code)
OTR(s)	Operational Test Requirement(s)
PCM	Pulse Code Modulation
PE	Project Engineer
PI	Principal Investigator
PM Tube	Photomultiplier Tube
PRD	Personal Radiation Dosimeter
PS	Payloads Specialist
PSS	Payloads Specialist Station

RFI	Radio Frequency Interference
r/m	Revolutions Per Minute
SAA	South Atlantic Anomaly
S&AD	Science and Applications Directorate
SAT	Systems Approach to Training
SCR	Strip Chart Recorder
SIM-SUP	Simulation Supervisor
SMMD	Small Mass Measurement Device
SMS-II	Spacelab Mission Simulation - Test II
SMSA	Skeletal Muscle Stress Apparatus
STI	Systolic Time Interval
STV	Science TV
T	Tesla
TBD	To Be Determined
Timeline	A chronological scheduling of events to rigorously control a sequence of operations
TOT	Test Operations Team
TPS	Test Preparation Sheet
TV	Television
VCG	Vectorcardiograph
VRMS	Volts Root Mean Square
WCS	Waste Collection System
ZPN	Impedence Pneumograph

LIFE SCIENCES SPACELAB MISSION SIMULATION-II
EXPERIMENTS AND OPERATIONS REQUIREMENTS

1.0 INTRODUCTION

This document is intended to be a single authoritative source for the Experiment Requirements (ER's) and Operational Test Requirements (OTR's) associated with Shuttle Mission Simulation-II (SMS-II).

The 15 experiments[1] (sec. 4.0) to be conducted during SMS-II were reviewed for suitability by the Life Sciences Directorate (LSD) Payloads Review Team, a Life Sciences Proposal Evaluation Group, the DE Project Engineering Team, and the Flight Planning Team. In addition to these 15 experiments, 6 experiments will be integrated into the SMS-II Spacelab mockup but will not be flight-planned because of timeline constraints.

The 15 experiments represent a Johnson Space Center (JSC) dedicated Life Sciences Spacelab and, combined with the 14 OTR's[2], will be performed during the seven-day simulated Shuttle mission to gain integration and operational insights into Shuttle Life Sciences mission planning and preparation.

This plan was assembled, edited, and documented by The Boeing Company under NASA Contract NAS 9-13655.

---

[1] *Development Plan*, DE-SMS-II-017, Life Sciences Spacelab Mission Simulation II. Sec. 6.0, table 6-I. July 28, 1975.

[2] Ibid. Sec. 5.0, table 5-I.

2.0 SCOPE

This document is intended to serve as a user's guide for the implementation and integration of ER's and OTR's associated with SMS-II. It will furnish the user with the respective test objectives, specific requirements, and technical information for the experiments and operational tests to be performed during SMS-II.

Criteria used for selection of SMS-II ER's and OTR's are contained in sections 4.0 and 5.0, EXPERIMENT REQUIREMENTS and OPERATIONS TEST REQUIREMENTS, respectively; methods for selection are addressed in the SMS-II *Development Plan* (DE-SMS-II-017) and are not included herein.

Specific test facility requirements are contained in the SMS-II *Facility Requirements* document (DE-SMS-II-016) and will not be addressed herein. Detailed information on data management requirements can be found in the SMS-II *Data Management Plan* (DE-SMS-II-040). Crew training, safety, stowage lists, checklists, and flight plans for SMS-II will be presented in other appropriate documents.

3.0 OBJECTIVES

The selection, implementation, and conduct of SMS-II experiments and operational tests will be accomplished with specific scientific and engineering objectives in mind. The degree to which these objectives are realized, and results obtained, will be addressed in the SMS-II Final Report.

3.1 SCIENTIFIC OBJECTIVES

The SMS-II scientific objectives are:

A. To develop representative life sciences experiments which are relevant to understanding and/or overcoming potential physiological problems, some of which were observed in past manned space flight programs.

B. To understand and assess operations of proposed life sciences and physical sciences experiments, including critiques of experiment procedures, hardware utilization, crew training requirements, and data management requirements.

C. To investigate the integration of potential experiments into optimal mixed payloads that would identify common usage equipment and/or data management techniques.

D. To investigate and develop zero-g processing of biological materials.

3.2 ENGINEERING OBJECTIVES

The SMS-II engineering and operational objectives are:

A. To evaluate the following in support of the Spacelab Preliminary Design Review:

- Habitability standards of Spacelab including lighting, cooling, common operational research equipment (CORE) segment provisions,

3.2 (continued)

- ° Current rack configuration,
- ° Rack/Floor substructure handling, and
- ° Overhead and subfloor stowage.

B. To demonstrate and to evaluate the handling of a payload from selection of experiments, through build-up, Levels III and IV integration, and check-out within the vehicle. This will include:

- ° Removable floor segment/rack configuration,
- ° Design routing for utilities required by various experiments,
- ° Prelaunch timeline access constraints,
- ° Proposed methods of experiment selection,
- ° Single experiment test facility,
- ° Methods of experiment arrangement, and
- ° Common life sciences laboratory equipment. To demonstrate and evaluate life sciences common laboratory equipment, the following will be included:
  - · Assessment of common life sciences laboratory equipment requirements to support the entire laboratory complement, once demonstrations are established.
  - · Assessment of problems related to multiusage time-sharing of common laboratory equipment.
  - · Establishment of specific requirements for common laboratory equipment through minitesting relative to such areas as waste management, sample temperature control, sterilization, and sample fixing.
  - · Evaluation of common equipment adaptability to calibration, maintenance, and troubleshooting, subject to the ability of ground-based engineers to establish real-time troubleshooting procedures for test subject usage during test.

3.2 (continued)

C. To demonstrate and to evaluate Spacelab/Orbiter payload station operations, including training, the following will be included:

- Development of the operational aspects of a Spacelab pallet/module mixed payload.
- Determination of placement of controls and displays in the Orbiter flight deck.
- Determination of criteria for crew complement.
- Development of training plans and training of the crew selected from various disciplines for the planned payload.

D. To demonstrate and to evaluate the operational and habitability aspects of the Orbiter/Spacelab combination, the following will be considered:

- Mid-deck sleeping accommodations,
- Shuttle galley system,
- Shuttle waste management system,
- Shuttle personal hygiene system,
- Shuttle water system,
- Stowage concepts,
- Food,
- Crew traffic through the mid-deck area,
- Two-shift crew operation,
- Trash management,
- Zero-g constraint systems for experiments, and
- Communications provisions.

E. To demonstrate and to evaluate data flow, timelining, and operational monitoring of a realistic mission profile, it will be necessary to:

- Provide a realistic evaluation of operational voice traffic and crew utilization by simulating Orbiter and Spacelab systems.

3.2 (concluded)

- Evaluate actual constraints on communication, including reduced satellite coverage and varying acquisition of signal/loss of signal (AOS/LOS) time intervals.
- Evaluate Baseline Operations Plan (BOP) staffing concepts.
- Evaluate a concept for a remote science monitoring area.
- Evaluate on-board flight planning by the crew.
- Evaluate the concept of Polaroid-type camera hard copy.
- Develop techniques/procedures for generating postmission reports during the conduct of the test.
- Evaluate experiments data management.

4.0 EXPERIMENT REQUIREMENTS

The experiments for SMS-II were selected in accordance with the following evaluation criteria:

A. Relevancy

- Does the experiment contribute to the long-range objectives of qualifying man for long-duration space flight?
- Does the experiment address an identified problem area?
- Will the data obtained answer the question asked?
- Will the experiment provide useful information for developing future flight experiments?

B. Technical Aspects

- Is the hardware available?
- Is the test hardware representative of the flight hardware?
- Is the experiment designed for potential common usage of equipment?
- Are the experiment procedures feasible, *i.e.:*
  - Can it be performed as early as required?
  - Can it be performed in the Orbiter?
  - Does it meet Spacelab constraints?
- Are the requirements for space, number of personnel, and amount of time consistent with the expected data return and its importance?
- Does the experiment challenge the Spacelab systems that need to be tested, *i.e.:*
  - Data management
  - Waste handling
- How much cost is involved?

An index of the SMS-II experiments and their requirements follow:

EXPERIMENTS REQUIREMENTS

NUMBER	TITLE	DESCRIPTION	PI*	PE**
SMS II-1	Hemodynamic Changes Following Exposure to Weightlessness	Study quantitative changes in limb blood flow and relative pulse wave velocity/time during flight and postflight.	A. E. Nicogossian, M.D.	R. W. Nolte
SMS II-2	Central & Peripheral Hemodynamic Responses during Isometric Exercise	Evaluate the effect of space flight on cardiovascular responses to isometric exercise.	S. A. [illegible], M.D.	A.V. Shannon, Jr.
SMS II-3	The Effect of Orbital Fluid Shifts on Cardiovascular Dynamics	Determine by myocardial responses reflected in Systolic Time Intervals central volume loading effects caused by headward fluid shifts and temporal course after orbit.	C. W. Hoffler, M.D.	J. D. Lem
SMS II-4	The Effect of Zero-g Fluid Shifts on the Vectorcardiogram	Determine by in-flight vectorcardiogram, etiology and consequences of fluid shifts, and potential countermeasures.	C. W. Hoffler, M.D.	R. W. Nolte
SMS II-5	Echocardiography	Evaluate changes in dimensions and cardiac mechanical & electrical function throughout cardiac cycle.	R. L. Johnson, M.D.	C. R. Booher
SMS II-6	Hemopoietic Function of Bone Marrow	Collect samples of bone marrow and hemopoietic tissue from experimental animals to evaluate functional aspects of the hemopoietic processes during space flight.	S. L. Bacon, Ph. D.	J. Lintott
SMS II-7	Pulmonary Blood Flow	Obtain data on the time course and magnitude of changes in central blood flow/volume relationships in zero-g by measuring pulmonary blood flow.	M. C. Bidoner, Ph. D.	J. D. Lem
SMS II-8	Respiratory Physiology and Pulmonary Function	Examine physiological mechanisms involved in adaptation of pulmonary system in zero-g and readaptation to Earth gravity.	C. F. Sawin, Ph. D.	J. D. Lem
SMS II-9	The Effect of Zero-g Fluid on Thermoregulation	Assess the effect of zero-g on the rate of heat transfer from the body.	J. M. Waligora	A.V. Shannon, Jr.
SMS II-10	Vestibular Function	Obtain ENG*** responses of human vestibular system to variable angular acceleration.	M. F. Reschke, Ph. D.	R. G. Thirolf
SMS II-11	Acute Fluid and Electrolyte Metabolism Responses to Space Flight	Identify acute changes in systemic physiologic factors that occur upon introduction of zero-g.	C. S. Leach, Ph. D.	R. G. Thirolf
SMS II-12	Study of Skeletal Muscle Function in Space Flight	Evaluate muscle dysfunction characteristics and consequences resulting from space flight disuse.	E. V. LeFevre, Ph. D.	C.R. Booher

*See Individual Experiments for Principal and Co-Principal Investigators

**Project Engineer

***Electronystagmogram

EXPERIMENTS REQUIREMENTS (continued)

NUMBER	TITLE	DESCRIPTION	PI	PE
SMS II-13	Salivary Analysis	Measure selected parameters of parotid saliva and relate to both oral and general health.	R. J. Frems, D.M.D.	C. R. Booher
SMS II-14	The Effect of Zero-g on Muscle-like Contractile Proteins	Determine effects of zero-g using rhythmic reversible protoplasmic streaming of the myxomycetes.	P. P. Mundy, Jr., Ph. D.	J. Lintott
SMS II-21	Cosmic Ray Magnetic Spectrometer	Measure the momentum and electrical charge of nuclei from cosmic radiation.	E. L. Goldwasser, Ph. D.	W. G. Davis

4.1 SMS II-1. HEMODYNAMIC CHANGES FOLLOWING EXPOSURE TO WEIGHTLESSNESS

Principal Investigator: *A. E. Nicogossian, M.D.*

Co-Principal Investigators: *G. W. Hoffler, M.D.; R. L. Johnson, M.D.; S. A. Bergman, Jr., M.D.; J. L. Baker*

Project Engineer: *R. W. Nolte*

A. Background

Cephalad fluid shifts were documented during Skylab manned missions. The impact of such fluid shifts upon the hemodynamics of the cardiovascular system has not yet been documented and analyzed. This experiment is designed to evaluate these changes as they occur in the peripheral vascular system and the generated information will be integrated into an overall assessment of cardiovascular function in space. Techniques to forestall cephalad fluid shifts will be developed, if possible.

Noninvasive techniques, which have been developed in the JSC Cardiovascular Laboratory, will be used under controlled experimental conditions to provide highly informative and quantitative assessments of peripheral hemodynamics. Preliminary results on increased limb blood flow, obtained during the Skylab 4 manned mission, are thought to be due to the occurrence of in-flight fluid shifts and decreased blood volume in the peripheral veins. This experiment will allow for a more quantitative evaluation to be made of the observed changes.

The sensors and signal conditioners used in this experiment have been shown to be well developed, accurate, and reliable during experimental tests involving acute head-down tilts. Data of increased quality coupled to minimal additional effort will be sought in performance of this experiment.

4.1 (continued)

B. Purpose

The purpose of this study in SMS-II is to initiate development of a space experiment to investigate changes in limb blood flow, and relative pulse wave velocity and time during orbital missions, as well as their temporal course after completion of the mission.

C. Participants

1. Number of Crewmen

Two or more crewmen will participate. The Mission and Payloads Specialists will serve as subjects.

2. Test Operations Team

The Test Operations Team (TOT) will be made up of the Principal Investigator (PI), Project Engineer (PE), Test Control Team, Mission Crew, Test Operations Personnel (Science Manager and others), Data Specialists, and support personnel.

D. Functional Objectives

To determine through performance, possible iterations, and analyses:

- The suitability of experiment hardware with respect to selection, development, and operability, and to optimize hardware packaging.
- The display and recording requirements external to the experiment.
- The crew training requirements.
- The crew procedures.
- The crew and experiment timelines.

4.1 (continued)

E. Performance Requirements and Conditions

1. Experimental Concept

A passenger/crewmember will be instrumented on the second, fourth, and sixth days of the mission. A minimum of 30 minutes will be required for each experimental session. Both position and activity of the subject will be specified and controlled. Data will be recorded on board and returned via magnetic tape for postflight computer analysis.

2. Outline of Implementation Method and Procedures

Data required:

- Bipolar lead of electrocardiogram (ECG)
- Phonocardiogram
- Carotid pulse wave
- Pneumogram
- Arm occlusion cuff trace and level of pressure
- Leg occlusion cuff trace and level of pressure
- Arm capacitance plethysmograph output data
- Leg capacitance plethysmograph output data
- Time
- Log of crew recording periods

Hardware configurations will allow operation, monitoring, and recording by the observer crewmember.

3. Protocol

a. Three earlier preflight reference recordings in supine rest position.

b. Three recordings in-flight in rest position on the second, fourth, and sixth days of the mission.

4.1 (continued)

c. Recordings as soon as possible after landing and serially thereafter until values return to baseline.

A minimum of two subjects will be required during SMS-II.

F. Environmental Requirements

The environment will be maintained according to specifications for the manned quarters of all compartments, in the Shuttle Orbiter and in any laboratory configuration, that crewmen may be expected to occupy as subjects in this experiment. Specifications will provide an acceptable comfort range for the subject and a reasonable approximation to the usual ground-based laboratory condition for this experiment.

G. Hardware Requirements

Rack mounting will be required for recorders and scopes. Smaller items will require drawer storage and a work surface for assembly of lead terminals and ancillary equipment to be installed on the test subject. The subject will require a movable litter or other support during testing in the supine position. Suitable electrical grounding and isolation will be required of the Development Test Unit (DTU) for safety of the subject.

Hardware items are as follows and are presently available:

- Tape recorder, 14-channel, Ampex Model FR 1300A or equivalent
- Occlusion cuff, two required
- Plethysmograph, two required
- Phonocardiograph, one required
- Pneumograph, one required
- Carotid sensor
- Vectorcardiograph (VCG), one-channel

4.1 (continued)

- Monitor scopes, seven-channel, two required
- Signal conditioners and pressure programers to support these sensors are available in breadboard form

H. System Interface

Bottled nitrogen gas at 6.9×10^5 N/m^2 (100 psi) will be required. A method of simulating downlink of data is TBD. Equipment integral to the experiment as listed in paragraph G will be furnished.

Power, compressed nitrogen, environment control, lighting, storage, and rack mountings will be furnished by the DTU. Power requirements are as follows:

- Tape recorder - 115 V, 48-62 Hz, 325 W
- Occlusion cuff pressure programer - 115 V, 3 A
- Plethysmograph signal conditioner - 115 V, 1 A
- Phonocardiograph signal conditioner - 115 V, 200 mA
- Pneumograph signal conditioner - 115 V, 1 A
- Carotid signal conditioner - 115 V, 1 A
- VCG signal conditioner - 115 V, 300 mA
- Monitor scopes - 115 V, 3 A, each

I. Data Support Requirements

All experimental data will be recorded on board using systems which are part of the experiment. Environmental data required for the experiment will be obtained by spacecraft (DTU) sensors. Photographic record requirements are TBD.

J. Flight Data File (FDF) Requirements

The following items will be required:

- A timeline of daily activities
- Detailed procedures and checklists
- A maintenance and troubleshooting guide

4.1 (concluded)

K. Preflight and Postflight Requirements

1. Preflight

Preflight requirements will include the assembly of the equipment in the flight configuration and the training of the subjects in the Cardiovascular Laboratory. Other requirements are TBD.

2. Postflight

Postflight requirements will consist of data retrieval and analysis. Other requirements are TBD.

L. Reporting

TBD in compliance with total mission requirements. Requirements can probably be met by a preliminary report at R+21 and a final report at R+60 days.

M. Training

Training requirements for flight crew and support personnel are TBD.

4.2 SMS II-2. CENTRAL AND PERIPHERAL HEMODYNAMIC RESPONSES DURING ISOMETRIC EXERCISE

Principal Investigator: *S. A. Bergman, Jr., M.D.*

Co-Principal Investigators: *R. L. Johnson, M.D.; G. W. Hoffler, M.D.; A. E. Nicogossian, M.D.*

Project Engineer: *A. V. Shannon, Jr.*

A. Background

Isometric exercise is now widely used in research and clinically to enable one to make quantitative evaluations of important autonomic control mechanisms of the heart and vascular tree. These evaluations are essential to the diagnosis of clinical pathology as well as to the early detection of latent disease states. It is reasonable and desirable that this capability be applied to such evaluations of man while he is in space.

Presently, measurements are well defined, reliable, and quantitative. A protocol system for precise and reproducible isometric contractions of selected skeletal muscle components is being constructed. These protocols, in conjunction with the appropriate hardware elements, are expected to provide potent and meaningful cardiovascular system evaluations.

B. Purpose

To initiate development of a space experiment which will enable measurement of the effect of space flight on cardiovascular responses to isometric exercise is the purpose of this study in SMS-II.

C. Participants

1. Number of Crewmen

   Pre-, in-, and postflight data will be required from a minimum of two subjects with orbital stays of at least five days' duration. Receipt of in-flight data will be

scheduled in such a fashion as to establish the temporal course of any observed changes.

2. Test Operations Team

The TOT will be made up of the PI, PE, Test Control Team, Mission Crew, Test Operations Personnel (Science Manager and others), Data Specialists, and support personnel.

D. Functional Objectives

To determine through performance, possible iterations, and analyses:

- The suitability of experiment hardware with respect to selection, development, and operability, and to optimize hardware packaging.
- The display and recording requirements external to the experiment.
- The crew training requirements.
- The crew procedures.
- The crew and experiment timelines.

E. Performance Requirements and Conditions

Exactly delineated muscle groups will be tested under reproducible isometric contraction loads. During standardized isometric exercise protocols for the upper limb, specific responses of the cardiovascular system will be measured. These will include physiological signals for the following determinations: ECG, Systolic Time Interval, blood pressure (BP) and heart rate (HR).

Effects on the cardiovascular system will be evaluated by multiple noninvasive measurements. In-flight differences in response will be determined from preflight reference data.

4.2 (continued)

Isometric exercise can produce effects of substantial magnitude, but their duration is fairly short. Other subject evaluations requiring basal states probably should not follow isometric exercise by closer than 15 minutes.

F. Environmental Requirements

All tests will be conducted in the Spacelab under conditions of comfort similar to any ground-based laboratory. External stimuli will be appropriately controlled. Preflight crew training is essential.

G. Hardware Requirements

1. Blood Pressure Measuring System (BPMS)

A commercially available noninvasive Skylab BPMS designed in commercial configuration will be used.

2. STI Measuring System - Breadboard

The same equipment designed for *The Effect of Orbital Fluid Shifts on Cardiovascular Dynamics* (experiment SMS II-3), including phonocardiogram, will be used.

H. System Interface

All equipment must be in close enough proximity to permit simultaneous instrumentation of one subject with all systems. The BPMS will be rack-mounted; no CORE support will be required.

	Electrical Power				
Item	Maximum (W)	Voltage (V)	Frequency (Hz)	Gas Type	Pressure
BPMS	130		60	N_2	$6.9 \times 10^5 N/m^2$ (100 psi)
STI	40	115	60		

4.2 (continued)

I. Data Support Requirements

Measurement Information

Equipment Items Used:

- Cardiotachometer
- Systolic Time Interval System
- Blood Pressure Measuring System
- Electromyograph
- Limb Volume Measuring System
- Isometric Exercise System
- Limb Occlusive Cuff System

4.2 (continued)

Data Measurements

Instructions: State the expected data measurement characteristics in the following format where applicable. Include additional or different information.

Parameter To Be Measured	Limb Volume Measurement	Isometric Exercise	Limb Occlusive Cuff Measurement
Expected Values of Parameter			
Average Value			
Range			
Measurement Characteristics			
Time/Day	1	1	1
Duration of each (min)	30	30	30
Total no. in mission			
Preflight	3	3	3
In-flight	Daily	Daily	Daily
Postflight	Daily for 3 times	Daily for 3 times	Daily for 3 times
Sample Rate	NA	NA	NA
Output Signal of Instrument			
Type	Analog	Analog	Analog
Frequency Range			
Low-to-High (Hz)			
Amplitude Range			
Instrument Resolution (percent total scale)			
Output Requirements			
No. of Channels	14	14	14
Sampling Rate	NA	NA	NA
Telemetry	NA	NA	NA
Recorder	NA	NA	NA
Time Identification Method			
Spacecraft clock or other	G.m.t. from time code generator or spacecraft clock	G.m.t. from time code generator or spacecraft clock	G.m.t. from time code generator or spacecraft clock

4.2 (concluded)

J. FDF Requirements

The following items will be required:

- A timeline of daily activities,
- Detailed procedures and checklists, and
- A maintenance and troubleshooting guide.

Since most equipment is also used for other experiments, access to these respective FDF's will be preferable to duplicate files.

K. Preflight and Postflight Requirements

1. Preflight

Preflight requirements will include assembly of the experiment hardware, installation, checkout, and pretest runs. Training will be initiated in the Cardiovascular Laboratory and completed in the DTU. Other requirements are TBD.

2. Postflight

Postflight requirements will include data retrieval and analysis, removal of the hardware, and reporting. Most data will be in the form of analog magnetic tapes and crew logs. Other requirements are TBD.

L. Reporting

TBD in compliance with total mission requirements. Requirements can probably be met by a preliminary report at R+21 and a final report at R+60 days.

M. Training

Training requirements for flight crew and support personnel will consist of four complete data runs with subject and observer. Each session will last one to two hours.

4.3 SMS II.3. THE EFFECT OF ORBITAL FLUID SHIFTS ON CARDIOVASCULAR DYNAMICS

Principal Investigator: *G. W. Hoffler, M.D.*

Co-Principal Investigators: *S. A. Bergman, Jr., M.D.;*
R. L. Johnson, M.D.;
A. E. Nicogossian, M.D.; J. L. Baker

Project Engineer: *J. D. Lem*

A. Background

Headward fluid shifts are a documented fact of manned space flight. However, neither the true magnitude, organ systems involved, time course, nor possible consequences have been determined at this time. This experiment is designed to assess an aspect of fluid shifts involving the vascular tree and specifically the effect(s) of theorized volume loading upon myocardial dynamics. Measurement of STI is a powerful noninvasive technique, and is readily amenable to this particular task for the overall clarification of fluid shifts and their effects.

Measurement of STI has become clinically useful in the past decade, largely attributable to the readily available accurate and acceptable reference data provided by invasive methodologies. Under controlled conditions, noninvasive STI measurements can provide highly informative and quantitative assessments of myocardial function. This is particularly true where volume loading is the factor in question.

Preliminary data were taken pre- and postflight on the Apollo 17 crewmen and more extensively on all Skylab crewmen. Findings show distinct alterations which are thought to be related to large fluid shifts having occurred in flight. No in-flight data exist, however, to corroborate the hypothesis. This experiment, proposed for the Apollo-Soyuz Test program earlier, was not

implemented. It is now considered suitable for early Shuttle flights.

B. Purpose

The purpose of this study in SMS-II is to develop a space experiment from which one can determine, by myocardial responses reflected in STI, central volume loading effects caused by headward fluid shifts and their temporal course after orbital achievement. Specifically, to assess from STI data certain cardiovascular effects due to fluid shifts, ECG (bipolar), Phonocardiographic, Carotid Pulse Time and Pneumographic data will be recorded to provide measurements of STI on specific crewmen at serially designated periods before, during, and after space flight.

C. Participants

1. Number of Crewmen

All crewmen will be trained for collection of orbital STI data. Two "subject" crewmen will undergo more detailed training for experiment development purposes. The crewmen will alternate as operator and subject.

2. Test Operations Team

The TOT will consist of the PI, PE, Test Control Team, Mission Crew, Test Operations Personnel (Science Manager and others), Data Specialists, and support personnel.

D. Functional Objectives

To develop the capability to record the signals necessary to measure STI in a simulated spacecraft environment is the main functional objective of this experiment. Other objectives are to determine through performance, possible iterations, and analyses:

- The suitability of experiment hardware with respect to selection, development, and operability, and to optimize hardware packaging.

- The crew training requirements.
- The crew procedures.
- The crew and experiment timelines.

E. Performance Requirements and Conditions

1. One crewman will be partially instrumented before launch so that a fellow crewman may accomplish the additional experiment requirements periodically, quickly, and accurately with provided monitoring accessories. Both position and activity of the subject crewman will be specified and controlled. Data will be recorded on board on magnetic tape which will be returned for postflight computer analyses.

2. Constraints

   All data will be from resting crewmen performing no significant work activity (> 75 W) the preceding half hour, and experiencing no environmental (*e.g.*, thermal) stress.

3. Outline for Implementation Method and Procedures

   - Data required
     - Bipolar lead of electrocardiogram
     - Phonocardiogram
     - Carotid pulse wave
     - Pneumogram
     - Time
     - Log of crew recording periods
   - Hardware configuration will allow operation, monitoring, and recording by a fellow crewman.
   - Protocol

     a. All data to be taken with crewmen "subjects" in equivalent launch position.

     b. Four preflight recording sessions of 5-minutes duration each - the last being within the hour before launch.

c. One crewman will have his data recorded continuously from 10 minutes before launch until 10 minutes after achieving simulated orbit.

d. Other subjects to have 5-minute recording sessions the first starting within the hour after achieving simulated orbit.

e. All subjects to have 5-minute recording sessions serially every hour thereafter for the first four hours in simulated orbit, then every two hours until the first sleep period, then three times the following day (about 0800, 1400, and 2000 hours, local time) and then twice daily (about 0800 and 2000 hours, local time) until return from simulated orbit; one 5-minute recording session will take place within the hour before simulated retrofire.

f. The same crewman selected for item c. will have his data recorded continuously from 10 minutes before simulated retrofire until 10 minutes after landing.

g. The other crewman subjects will have 5-minute recording sessions starting as soon as feasible after simulated landing (not > 1 hour), and serially thereafter at frequencies similar to those upon going into orbit.

F. Environmental Requirements

Environment will be maintained according to specifications for the manned quarters of all compartments in the Shuttle Orbiter and in any Spacelab module configuration where crewmen may be expected to participate as subjects in this experiment. More specifically, it should be within the acceptable comfort range for the subject and provide a reasonable approximation to the usual ground-based laboratory conditions for this experiment.

G. Hardware Requirements

Equipment required for this experiment consists of the following:

1. Vector Programmer

This rack-mounted commercial device (Hewlett Packard, Palo Alto, CA, Model 1507A), will condition three leads of ECG; however, only one channel is required for this experiment. Three body electrodes, in the Skylab configuration, will provide the subject interface; the fourth electrode is the ground.

2. Systolic Time Interval Module

This package contains signal conditioning for phonocardiogram, carotid pulse wave, and pneumogram. The present configuration is a portable package which could be readily mounted on a shelf in one rack to support SMS-II. Profile is shown in figure 4-1.

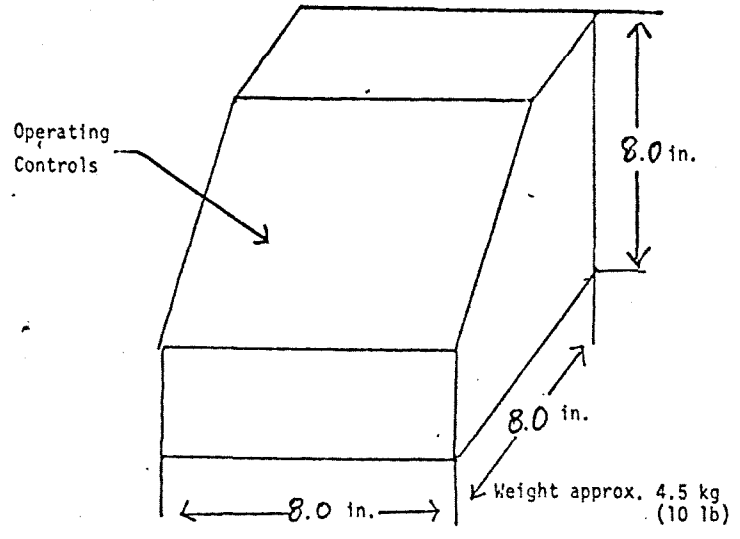


Figure 4-1. STI Module.

4.3 (continued)

3. Time Code Generator

A commercial rack-mounted Time Code Generator (Systron-Donner, Concord, CA, Model 8150 or equivalent) is required for time-coding of recorded data. This generator must be synchronized with spacecraft time. Alternatively, a time code from the spacecraft clock could be used.

4. Magnetic Tape Recorder

A Tandberg (Berkeley, CA, Model 100) four-channel, FM Magnetic Tape Recorder will be used to record the four data channels and the time code. Recording of the five channels on the four-track recorder is obtained through analog multiplexing of the ECG and pneumogram. Standard 1/4-inch tape in seven-inch reels will be utilized with this recorder. Each reel provides one hour of recording time. The recorder will be mounted on a shelf or in a drawer for SMS-II such that the controls are readily available. Access for changing the tape is required also.

5. Subject Harness

A harness is required consisting of the three ECG electrodes, phonocardiogram transducer (Elema-Schonander, Sieman's Corp., Dallas, TX, Model EMT25C), carotid pulse transducer (HP Model APT16-1), and a thermistor head-mounted pneumograph along with cables for connecting to the rack-mounted signal conditioner. Expendables will include electrolyte sponges, wet wipes, and attachment tapes for the electrodes and ECG microphone.

4.3 (continued)

6. Attachment of Sensors

a. Attach four ECG electrodes as follows:

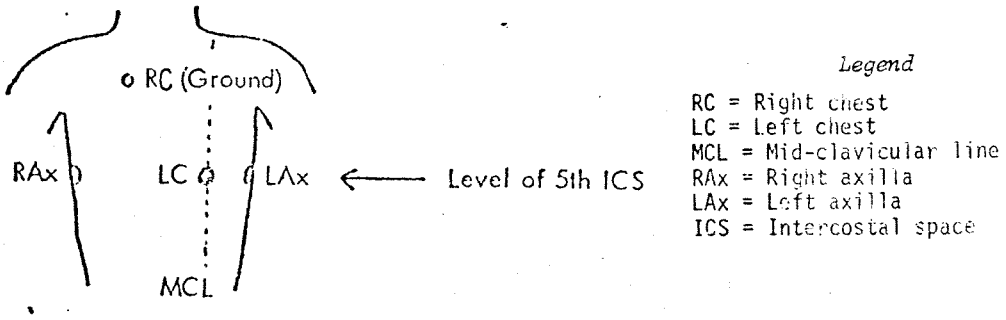


Figure 4-2. Position of ECG Electrodes.

b. Prepare skin sites with supplied wipes, rub vigorously and dry. Use Skylab-type double adhesive stomaseals and sponge inserts. Attach appropriate leads from VCG umbilical.

c. Apply the phonocardiograph pick-up with an adhesive stomaseal at third or fourth intercostal space (ICS), left sternal border, for optimal intensity of heart sounds.

d. Attach the thermistor pneumograph probe with head piece and swing to optimal position just below nares.

e. Apply the carotid sensor with an adhesive stomaseal, after optimal signal trace position is located and lightly secure with neck band.

All equipment with the exception of the analog multiplexer for the tape recorder is available and operational in the PI's laboratory. The multiplexer may be easily designed using currently available electronic components.

H. System Interface

The hardware will require one mounting rack and drawer space for storage of supplies. Power requirements are as follows:

Item	Electrical Power Maximum (W)	Voltage (Va.c.)	Frequency (Hz)
Vector Programmer	35	115	60
Time Code Generator	55	115	60
Tape Recorder	38	115	60
STI Module	40	115	60

I. Data Support Requirements

Data analyses will be performed postmission using the existing system in the Cardiovascular Laboratory.

J. FDF Requirements

The following documents will be required:

- A timeline of daily activities.
- Detailed procedures and checklists.
- A maintenance and troubleshooting guide.
- Access to the respective FDF's will be preferable to duplicate files for CORE items used.

K. Preflight and Postflight Requirements

1. Preflight

Preflight requirements will include assembly of the experiment hardware, installation, checkout, and pretest runs. Training, initiated in the Cardiovascular Laboratory, will be completed in the DTU. Baseline data are required on all subjects.

A communication link will be necessary for the PI to advise on experiment conduct and the PE to assist in troubleshooting.

Data display outside the DTU will not be required.

2. Postflight

Postflight requirements will include data retrieval and analyses, removal of the hardware and reporting.

L. Reporting

TBD in compliance with total mission requirements. Requirements can probably be met by a preliminary report at R+21 and a final report at R+60 days.

M. Training

Training requirements for flight crew and support personnel are TBD.

4.4 SMS II-4. THE EFFECT OF ZERO-G FLUID SHIFTS ON THE VECTORCARDIOGRAM

Principal Investigator: *G. W. Hoffler, M.D.*

Co-Principal Investigators: *R. L. Johnson, M.D.;*
S. A. Bergman, Jr., M.D.;
A. E. Nicogossian, M.D.; P. F. Hogan, Ph. D.

Project Engineer: *R. W. Nolte*

A. Background

Vectorcardiographic changes observed on Skylab crewmen, while considered to be of no clinical concern, are real and statistically significant. Etiologic mechanisms, moreover, are undetermined and hence the true meaning cannot be known. This experiment is designed to provide a more specific estimation of the in-flight onset, progression, and time course of these changes. Such data will allow the assessment of causal relationships of vectorcardiographic findings and body fluid shifts. The latter is an obvious area of prime concern, and all avenues of clarification must be utilized. This particular experiment should produce information bearing directly on this subject.

Electrocardiographic interval changes suggesting effects of increased vagal tone were observed early in some Gemini crewmembers. On several crewmembers of early Apollo flights, postflight increases in electrocardiographic wave amplitudes were suspected, but no true quantitation was possible. Vectorcardiograms were included in pre- and postflight crew evaluations of the last three Apollo flights for the first time to allow quantitative measurements of electrocardiographic signals from American space crews. Definitive postflight changes observed were increased P and QRS vector magnitudes and shifts in their orientation, compared to preflight references. At that time, it was assumed that these changes were manifestations of exaggerated responses to orthostatic stress after return from orbit.

Skylab data provided a further important step to our understanding by exhibiting significant in-flight changes, even as early as the fourth day in-flight (the earliest available data). At the present, it is hypothesized that these electrocardiographic changes are related in some way to rather prominent in-flight fluid shifts, that were documented from Skylab data also.

It is believed that continuous and/or serially, periodic vectorcardiograms recorded on space crewmen from the prelaunch phases, through launch and orbital entry and beyond, will provide a definitive time history of changes. This will allow confident appraisal of the theorized relationship. It is considered in the best interest of data quality and control of experimental design to acquire these data unencumbered by other experiment or crew requirements. Therefore, dedicated, miniaturized, self-contained experiment hardware will be utilized for all data acquisitions.

B. Purpose

The purpose of this study for SMS-II is to develop systems and techniques to convert the VCG, as first used in Skylab, into a Spacelab/Orbiter experiment to accomplish all phases of the mission and to permit association of VCG parameters with other events occurring in null gravity, especially in-flight fluid shifts.

C. Participants

1. Number of Crewmen

Two or more crewmen alternating as operator and subject.

2. Test Operations Team

The TOT will be made up of the PI, PE, Test Control Team, Mission Crew, Test Operations Personnel (Science Manager and others), Data Specialists, and support personnel.

4.4 (continued)

D. Functional Objectives

To determine through performance, possible iterations, and analyses:

- The suitability of experiment hardware with respect to selection, development, and operability, and to optimize hardware packaging.
- The display and recording requirements external to the experiment.
- The crew training requirements.
- The crew procedures.
- The crew and experiment timelines.

E. Performance Requirements and Conditions

1. Passenger crewmen will be instrumented before launch and on landing day in such a manner as to allow either continuous or on-demand recordings of their vectorcardiograms. Except for the immediate period around launch and landing, when hardware mounted in the Orbiter must be used, it will be the crew option to perform recording sessions with the Orbiter or the Spacelab hardware. Both position and activity of the "subject" crewman will be specified and controlled. Data will be recorded on board and returned via magnetic tape for postflight computer analyses.

2. Outline of implementation methods and procedures:

   - Data required
     - X-, Y-, and Z leads of Frank vectorcardiogram
     - Time
     - Log of crew recording periods
   - Hardware configuration will allow complete operation of system and recording of data from the "subject" crewman.

4.4 (continued)

- Constraints
  - All data will be from resting crewmen postprandial by approximately one hour and performing work activity less than 75 W the preceding half hour. The environment will be kept free of thermal stress.
- Protocol
  - All data to be taken with crewmen subjects in equivalent launch position.
  - Four preflight recording sessions of 5-minutes duration each, the last being within the hour before launch.
  - One crewman will have his data recorded continuously from 10 minutes before launch until 10 minutes after achieving orbit, and later from 10 minutes before retrofire until 10 minutes after landing.
  - Other crewmen subjects to have 5-minutes recording sessions within the hour after achieving orbit and later 5-minute recording sessions as soon as feasible after landing (not > 1 hour), and serially thereafter at frequencies similar to those upon going into orbit.
  - All crewmen subjects to have 5-minute recording sessions serially every hour thereafter for the first four hours in orbit, then every two hours until the first sleep period, then three times the following day (about 0800, 1400, and 2000 hours, local time) and then twice daily (about 0800 and 2000 hours, local time) until return from orbit; one 5-minute recording session to take place within the hour before retrofire.
  - Postflight monitoring will determine how long to continue these recordings. Based on previous experience, recordings will be continued at least through R+2 days.

4.4 (continued)

- For an actual launch, all crewmen subjects will have at least two 5-minute recording sessions (about 0800 and 2000 hours, local time) on each of four different days (not including launch day), preferably separated in time by as much as one month before launch.
- In order to establish a reasonable baseline of their normal circadian variability in STI, it is highly desirable to record six sessions (about every two hours) on one preflight day (about F-15).
- Procedure
  - Power up all systems.
  - Prepare skin sites with supplied wipes; rub vigorously and dry.
  - Apply electrodes with Skylab-type double adhesive stomaseals and sponge inserts.
  - Attach appropriate leads from VCG umbilical.

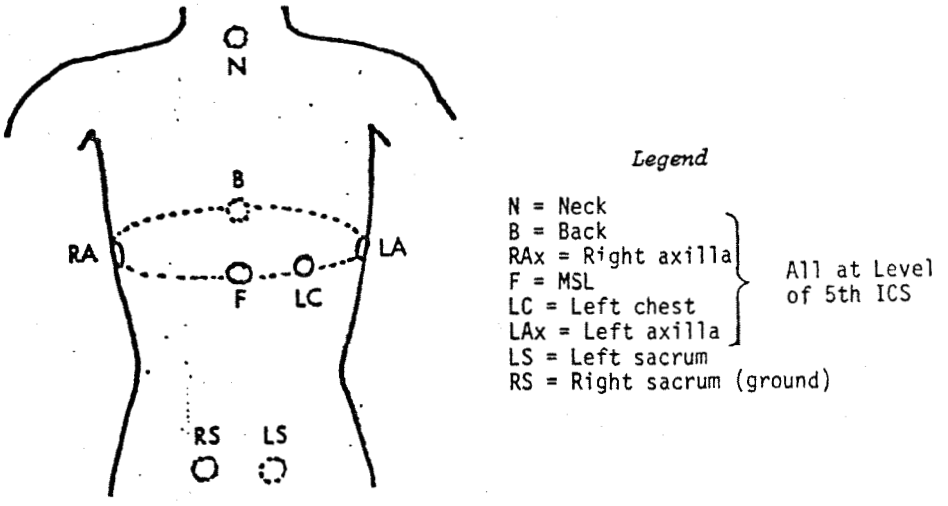


Figure 4-3. Placement of Electrodes.

- Monitor and record the data: observer/monitor will assure adequacy of all three leads (by wave form, amplitude, S/N ratio, position, and stability) and time code, then activate recording system for five minutes. Record in log: time of beginning, crew ID,

date, and any pertinent comments. (Subject must remain quiet and motionless during recording).

- Take-down, clean-up, stowage - system off.

F. Environmental Requirements

Environment will be maintained according to specifications for the manned quarters of all compartments in the Shuttle Orbiter and any Spacelab Module configuration where crewmen may be expected to participate as subjects in this experiment. More specifically, it will be within the acceptable comfort range for the subject and provide a reasonable approximation to the usual ground-based laboratory conditions for this experiment.

G. Hardware Requirements

The experiment hardware consists of the following:

- Tandberg instrumentation tape recorder Series 100. Four-channel.
- Hewlett Packard Vector Programmer Model 1507A.
- Systron-Donner Time Code Generator Model 8150.
- Electrode harness with eight body surface electrodes - similar to Skylab configuration.

The above equipment is presently available in rack-mounted or portable configuration. However, this hardware configuration will not satisfy the experiment protocol outlines for space without complete miniaturization.

H. System Interface

Rack space (less than one rack, total) is required for mounting, and drawer space for storage of supplies. The VCG will be used on several experiments, therefore the mounting provisions should have sufficient latitude to serve in multiple locations.

4.4 (continued)

The desired location of this equipment is in close proximity to the "subject" crewman, since continuous recording is required from 10 minutes before launch until 10 minutes after achievement of orbit and during a similar time span at reentry. This also implies high portability, stowage space in the Orbiter, and access to Orbiter power until the hardware can be transferred to the payloads experiment module or alternate hardware made accessible. Following orbital insertion, power and storage space in the payloads experiment module may be desirable until reentry.

The following utilities are required to support the experiment in its present configuration:

	Electrical Power		
Item	Maximum (W)	Voltage (V±10%)	Frequency (Hz)
Tape Recorder	38	115/230	48-100
Vector Programmer	30	115/230	50/60
Time Code Generator	55	115/230	48 to 62

I. Data Support Requirements

Only postmission analyses of data are desired. This will be performed in the existent facility in the Cardiovascular Laboratory/Data Systems and Analysis Directorate (DSAD).

J. FDF Requirements

The following documents will be required:

- A timeline of daily activities.
- Detailed procedures and checklists.
- A maintenance and troubleshooting guide.
- Since most equipment is also used on other experiments, access to those FDF's will be preferable to duplicate files.

4.4 (concluded)

K. Preflight and Postflight Requirements

1. Preflight

Preflight requirements will include assembly of the experiment hardware, installation, checkout, and pretest runs. Training will be initiated in the Cardiovascular Laboratory and completed in the DTU. Other requirements in TBD.

2. Postflight

Postflight requirements will include data retrieval and analyses, removal of the hardware, and reporting. Photographic coverage is requested. Data analyses will be performed by machine methods in the Cardiovascular Laboratory.

L. Reporting

TBD in compliance with total mission requirements. Requirements can probably be met by a preliminary report at R+21 and a final report at R+60 days.

M. Training

Training requirements for flight crew and support personnel are TBD.

4.5 SMS II-5. ECHOCARDIOGRAPHY

Principal Investigator: *R. L. Johnson, M.D.*

Co-Principal Investigators: *G. W. Hoffler, M.D.;*
A. E. Nicogossian, M.D.;
S. A. Bergman, Jr., M.D.; J. L. Baker

Project Engineer: *C. R. Booher*

A. Background

Echocardiography is a noninvasive technique which has rapidly gained wide acceptance both as a clinical diagnostic and a research tool in cardiology. The technique will be particularly useful in the Shuttle era as an in-flight means of determining changes in cardiac wall thickness, cardiac chamber volumes, myocardial contractility, stroke volume, and cardiac output. Cardiovascular data obtained during Skylab flight suggest that, at least early in flight, volume overloads were presented to the pulmonary vessels and the right heart. Blood pressure patterns at rest, not obtainable before the fourth day of flight, were consistent with an increased stroke volume and cardiac output. Whether these changes actually occur in weightlessness can be verified by echocardiography. Understanding of cardiac adaptations to the alterations in volume and distribution of regional fluid compartments and in blood volume brought about by weightlessness can be markedly expanded. Such understanding would provide a much firmer foundation than now exists for predicting the cardiovascular changes to be expected during prolonged space flight.

The first application of echocardiography in examining the effects of space flight on the heart occurred during the pre- and postflight evaluations of the Skylab 4 astronauts. These examinations revealed that 84 days of weightlessness had resulted in no detectable changes in the Commander and only slight changes in the Scientist Pilot and Pilot, approximately 15 percent reduction in stroke volume and no reduction in wall thickness.

4.5 (continued)

No deterioration in cardiac function was evident. Changes noted a few hours after splashdown persisted through 11 days. The observations of the crewmen had disappeared by 31 days after splashdown.

The relatively new usage of reflected ultrasonic waves to measure cardiac dimensions has gained wide acceptance in clinical and research cardiology. Numerous reports comparing values obtained by echocardiography with those from other more direct and invasive measurements have appeared in the scientific literature. Its widespread and increasing application to clinical medical problems has established echocardiography as one of the most productive and reliable noninvasive methods for evaluating cardiac dimensions and function. A number of excellent echocardiographic systems are available off-the-shelf. In view of the increasing application of this noninvasive method to new and different problems in cardiology, it seems inevitable that the state-of-the-art will continue its rapid advancement. Already it appears to be uniquely valuable as a method to study cardiac function during weightlessness.

In-flight cardiovascular studies during the Skylab missions indicated that many changes affecting cardiac function had already occurred by the time cardiovascular data first became available on the fourth day of flight. Since a headward shift of body fluids was a prime factor in these changes and the major avenue of transfer of fluids was via the vascular system, major responsive changes in cardiac function and hemodynamics must have taken place in the first few hours of flight. While adaptive cardiovascular change continued for many days, it appears that the rate of change decelerated with time, achieving relative stability after five to seven weeks.

The brief Shuttle flights appear to offer an excellent opportunity to study these early changes in a large number of individuals,

and echocardiography appears to offer a uniquely valuable technique to use in studying them. Even though vectorcardiography can probably be obtained even earlier in flight, it will be obtained simultaneously with echocardiography. Correlation of data from these two methods will add dimension to the understanding of the cardiac responses to weightless space flight. Although not planned for SMS-II, specific intervention such as lower body negative pressure to reduce preload, isotonic exercise such as handgrip to increase afterload, or vasoactive drugs which alter these, would furnish additional valuable information concerning cardiac function and may be proposed for future flight studies.

B. Purpose

The purpose of this study in SMS-II is to develop a space experiment which will enable measurement of changes in cardiac dimensions and mechanical and electrical events during the cardiac cycles to be made. It will combine echocardiography, vectorcardiography, and quantitative measurements of the following: movements of the mitral valve, left ventricular and atrial diameter and volume, and septal and left ventricular wall thickness. Rate of wall movemements (index of myocardial contractility) during the cardiac cycle will be measured in a quantitative fashion throughout the cardiac cycle. From these data, stroke volume and cardiac output will be estimated. A vectorcardiogram will be simultaneously recorded to show changes in electrical activity. These measurements will be repeated periodically during the period of simulated flight.

C. Participants

1. Number of Crewmen

Two crewmen subjects; one will be a medically trained operator.

2. Test Operations Team

The TOT will consist of the PI, PE, Test Control Team, Mission Crew, Test Operations Personnel (Science Manager and others), Data Specialists, and support personnel.

D. Functional Objectives

To determine through performance, possible iterations, and analyses:

- The suitability of experiment hardware with respect to selection, development, and operability, and to optimize hardware packaging.
- The display and recording requirements external to the experiment.
- The crew training requirements.
- The crew procedures.
- The crew and experiment timelines.

E. Performance Requirements and Conditions

The performance requirements and conditions will be as follows:

1. To activate vectorcardiographic and echocardiographic systems and analog tape recorder (including time-code).
2. To apply VCG electrodes and connecting cable.
3. To calibrate both systems.
4. To have subject assume a left lateral recumbent position.
5. To have observer prepare the echo probe and the skin in fourth interspace at left border of subject's sternum.
6. To have observer position the probe to focus on desired cardiac structure and activate the fiberoptic Strip Chart Recorder (SCR).
7. To have observer position probe to scan through septum and free wall of left ventricle at its greatest diameter.
8. To recalibrate both systems.

9. To deactivate strip chart recorder, tape recorder, VCG and echo systems.
10. To label the strip chart record with subject's identity, date and time.
11. To store the strip chart and magnetic tape for return.

F. Environmental Requirements

All tests will be conducted in the Spacelab under comfort conditions usually obtained in any ground-based laboratory.

G. Hardware Requirements

The major piece of equipment, that used for postmission testing of the Skylab 4 crew, to be utilized to support this experiment is an "Ekoline 20" diagnostic ultrasonoscope with associated display, recording, and transducing accessories. The electrocardiographic input required for the functioning of the ultrasonoscope can be provided by a VCG system as outlined in section 4.4. The experiment subject will be placed in a supine position during the data-taking phases of this experiment on either a simple collapsible cot of some type or a 2-meter long foam pad which may be placed on the facility floor.

The magnetic tape recording capability, for collection of VCG data, in conjunction with a G.m.t. code format will be fed into the ultrasonoscope strip chart recorder.

H. System Interface

The system may be mounted anywhere in the Spacelab mockup providing the controls are easily accessible and the displays easily seen by the crewmember conducting the experiment. The ultrasonoscope equipment, mounted in a standard 47.5 centimeters (19-inch) instrumentation rack, requires approximately 600 W of the available 115 V 60 Hz power when being operated. A data downlink simulation will be required for display to the PI.

I. Data Support Requirements

A magnetic tape system will be required for VCG recording and a timing system for tape and Strip Chart Recorder.

J. FDF Requirements

The following items will be required:

- A timeline of daily activities.
- Detailed procedures and checklists.
- A maintenance and troubleshooting guide.

Since some equipment is also used with other experiments, access to these respective FDF's will be preferable to duplicate files.

K. Preflight and Postflight Requirements

1. Preflight

Preflight requirements will include assembly of the experiment hardware, installation, checkout, and pretest runs. Training will be initiated in the Cardiovascular Laboratory and completed in the DTU. Other requirements are TBD.

2. Postflight

Postflight requirements will include data retrieval and analyses, removal of the hardware, and reporting. Most of the data will be in the form of SCR's from the ultrasonoscope. Photographic coverage of the experiment in the DTU will be required.

L. Reporting

TBD in compliance with total mission requirements. Requirements can probably be met by a preliminary report at R+21 and a final report at R+60 days.

4.5 (concluded)

M. Training

Specific training requirements for flight crew and support personnel are TBD. The medical crewman must have sufficient training to understand operation and adjustments of echo system. He must also learn patterns of reflected waves to determine proper position of probe. He must learn proper preparation and placement of VCG electrodes and operation of the vectorcardiograph.

4.6 SMS II-6. HEMOPOIETIC FUNCTION OF BONE MARROW

Principal Investigator: S. L. Kimzey, Ph. D.
Co-Principal Investigators: W. H. Crosby, M.D.; Mehdi Tavassoli, M.D.
Project Engineer: J. Lintott

A. Background

The most consistent and significant hematological consequence of manned space flight has been the loss of red cell mass by the crewmen during the flight interval. Data from the combination of actual Earth orbital and translunar space flights and of ground-based simulation studies strongly suggest that weightlessness is the primary causative agent. The mechanism by which this influence is effected, however, is unknown, but the results of all the studies after the Gemini missions implicate the erythropoietic processes as opposed to a hemolytic event. Regardless of whether the primary cause of the red cell mass loss is by inhibition of bone marrow function and hence production, or by premature sequestration of red cells by the reticuloendothelial system, replacement of the lost red cells does not occur immediately.

Not only is the compensatory erthropoiesis delayed in weightlessnes, but a return to the normal terrestrial gravitational environment does not immediately stimulate red cell production. Data from the Apollo and Skylab flights indicate a delayed recovery of red cell mass during the postexposure period; recovery of red cell mass did not occur as late as several weeks after some missions. Because the red cell life span stabilized early during the postexposure period, the delayed recovery of red cell mass indicates that the hemopoietic function remains suboptimal. From what is known of the hemopoietic function of marrow, this delayed recovery suggests adventitial injury to the bone marrow.

4.6 (continued)

The regenerative adventitial boundary of bone marrow is well-defined and consists of proliferating fibroblastic tissue. By measuring the distance this regenerative boundary moves along the length of bone marrow cavity, one may then give a quantitative dimension to the process of stromal repair.

Over a recent three month period, more than 200 rats were examined to determine the chronology of this stromal process. It has been determined when each of the nine steps begin (para. E), at what point it reaches its developmental peak and at what time the process is completed.

For SMS-II, rats will be prepared at varying times during the two weeks prior to initiation of the test. Test data indicate that hemopoietic proliferation and expansion begin in the bone marrow six to seven days after the ablation of the femoral cavity. Total regeneration is completed in ten more days. Rats will be sacrificed at varying times during the simulated flight (exact time intervals to be determined) and the bone marrow samples removed and chemically fixed for postflight sectioning and microscopic examination.

At the same time that the bone samples are collected, specimens of whole blood and splenic tissue will also be removed, fixed, and returned for postflight examination.

Later refinements of this experimental protocol for the actual Shuttle flights will include collection of other tissue and blood serum samples for additional analyses of hemopoietic functions and the concentrations of regulating plasma-borne hormones.

Hemopoietic function of the bone marrow depends, on the one hand, upon proliferating hemopoietic cells and, on the other

hand, upon a unique adventitial microstructure that supports hemopoiesis. When hemopoietic depression results from transient insult to proliferating hemopoietic cells, the recovery after the cessation of insult is relatively rapid. On the other hand, the marrow adventitia has a relatively slower turnover rate and its recovery after a transient insult is slow. Thus, when the hemopoietic depression results from injury to the marrow's supporting adventitia, the hemopoietic recovery is delayed. The delayed recovery of red cell mass in the postexposure period may, therefore, indicate injury to the marrow's supporting structure.

B. Purpose

The purpose of this study in SMS-II is to develop a space experiment which will enable evaluation of functional aspects of the hempoietic processes in bone marrow and related tissues in zero-g.

This protocol outlines simple surgical techniques, by which samples of bone marrow and related hemopoietic tissues from experimental animals (white rats) may be acquired, and preparation of these tissues by chemical fixation for postflight microscopic analysis may be made. The anlayses are designed to evaluate the functional aspect of the hemopoietic processes in bone marrow and related tissues. These procedures, when performed in an actual Shuttle flight, will contribute significant information relative to the inhibition of erythrocyte production and concomitant loss of circulating red cell mass, observed during the Gemini, Apollo, and Skylab manned flights.

C. Participants

1. Number of Crewmen

One.

2. Test Operations Team

The TOT will include the PI, PE, Test Control Team, Mission Crew, Test Operations Personnel (Science Manager and others), Data Specialists, and support personnel.

D. Functional Objectives

To determine through performance, possible iterations, and analyses:

- The adaptability of the experimental protocol to Spacelab accommodations.
- The analyzability of the specimens prepared in the Spacelab environment.
- The suitability of experiment hardware with respect to selection, development, and operability, and to optimize hardware packaging.
- The display and recording requirements external to the experiment.
- The crew training requirements.
- The crew procedures.
- The crew and experiment timelines.

E. Performance Requirements and Conditions

Two models for studying bone marrow stromal repair after injury are being used. The first model consists of disruption of a marrow core and marrow stroma in the rat femur by inserting and withdrawing a slender trocar from the whole length of femur. This is done by opening the knee joint, drilling a hole in the articular surface of the femur until the marrow cavity is reached. The operation is simple and rapid. The sequence of repair process is similar to the sequence of marrow regeneration after autotransplantation of marrow fragments to ectopic sites and comprises nine well-defined steps:

4.6 (continued)

1. Hemorrhage
2. Fibroblastic proliferation
3. Osteoblastic differentiation
4. Osteoid bone formation
5. Formation of primordial marrow cavity
6. Formation of marrow sinusoidal system
7. Appearance of hemopoietic cell foci
8. Hemopoietic cell production and expansion
9. Bone resorption

The second model is ablation of femoral cavity by a polyethylene tube, using a surgical technique similar to that described for the first model. In this model, a rim of marrow is left in the proximal end of the femur. Repair of marrow originates from this rim and gradually moves down to replace the ablated portion of the marrow. All nine steps, as described above, are seen.

Ideally, two animals would be sacrificed and processed per day for flight. This would depend heavily on the time required for performing the operations by the particular crewman. The entire in-flight procedure including preparation, surgery, closeout, cleanup, and storage of the samples should require no more than 30 to 60 minutes per day to process two animals. The exact timelines will have to be established during the preflight training period.

Day-to-day maintenance of the animals would normally be automated in the true flight situation. However, for this test, routine housecleaning and feeding of the animals may require some support. A communications link between the PI and the crewman during preparation of the tissues is desirable.

F. Environmental Requirements

All tests will be conducted in the Spacelab under comfort conditions usually obtained in any ground-based laboratory. The fixed tissue samples must be maintained at 4-8 °C without freezing and the fixative itself should be stored at these temperatures prior to being used.

G. Hardware Requirements

Cages for housing and maintaining 6-12 white, male Wistar rats (500 gram body weight) in the Spacelab will be required. These cages need not be zero-g qualified, but can be any type of mockup that is available. Purina Lab Chow and tap water should be provided *ad libitum*. All surgical instruments, surgical animal board, sample storage vials, and reagents will be off-the-shelf items provided by the PI. A refrigerator should be provided for storage of fixed samples at a temperature of 4-8 °C.

NOTE: The samples must not be frozen.

Rack space requirements will be one or two drawers for storage of experiment equipment and supplies.

H. System Interface

Sharing of utilities, environment, refrigerator storage, waste handling, rack storage, a work place, and possibly a spotlight for surgical illumination are forecast. Access to notepads, voice tape, or a keyboard will be required to prepare experiment logs.

I. Data Support Requirements

The only data collected during the flight will be the date and time at which each sample is collected. This information can be logged in any convenient manner. Provision will be made to record and play back the narratives from the crew on care of the animals and microscopic observations.

Postflight data will consist of microscopic examination of the various tissues and plotting the kinetic relationship of each of the nine stages of bone marrow regeneration with time. Red cell shapes will be classified as will the general morphological appearance of the spleen. Close attention will be paid to the quality of the samples prepared "in-flight" compared to those prepared under ideal laboratory conditions.

J. FDF Requirements

FDF requirements will include:

- A timeline of daily activities.
- Detailed procedures and checklists.

K. Preflight and Postflight Requirements

1. Preflight

Preflight requirements will include assembly and installation of the experiment hardware and pretest runs. Training will be initiated in the Cellular Analysis Laboratory and completed in the DTU.

At least one member of the crew will require training in the surgical removal of the bone, spleen, and blood samples from the experimental rats, and in the chemical fixation of each type of tissue. This will require no more than four three-hour sessions prior to the flight. The exact time required will depend on the individual's past experience and his ability to perform the operations.

The animals will have to be placed and maintained in the Spacelab prior to "launch."

2. Postflight

Postflight requirements will include retrieval of logs and

specimens, removal of the hardware, and reporting. Samples will remain at 4-8 °C until delivery to the PI. Logged data will be returned with samples.

L. Reporting

TBD in compliance with total mission requirements. Requirements can probably be met by a preliminary report at R+21 and a final report at R+60 days.

M. Training

Detailed training requirements for flight crew and support personnel are TBD. Training goals are listed in paragraph K.

4.7 SMS II-7. PULMONARY BLOOD FLOW

Principal Investigator: M. C. Buderer, Ph. D.
Co-Principal Investigator: J. A. Rummel, Ph. D.
Project Engineer: J. D. Lem

A. Background

Measurements of cardiac output during postflight exercise tests in the Skylab astronauts revealed that significant reductions in blood flow and stroke output of the heart were observable in the immediate postflight period. One to two weeks were required for these parameters to return to their preflight levels, and it was hypothesized that these changes were associated with the replenishment of blood volume lost during the period of weightless exposure. This blood loss is presumed to occur as a result of a cephalad shift in blood volume accompanying entry into the zero-g environment. Thus, in zero-g, blood tends to be shifted from the lower extremities and abdomen toward the thorax and the head.

It can be postulated that the increased thoracic or "central" blood volume encountered in zero-g will produce at least transient increases in pulmonary blood flow and more uniform pulmonary perfusion. Unfortunately, the lead times required for the Skylab medical experiments did not allow for the inclusion of the in-flight measurements of pulmonary blood flow and thus, the presence of these flow transients could not be verified.

The Space Shuttle will provide an opportunity to investigate the blood flow changes associated with weightlessness. Sequential measurements of pulmonary blood flow (cardiac output) during the first few hours or days of the mission may provide an index of both the time course and magnitude of changes in central blood flow/volume relationships.

Since changes in blood flow represent the critical adaptive responses to changes in physical exercise levels, the capability for in-flight measurement of blood flow (cardiac output) would also constitute an important adjunct to the investigation of the physiological response to exercise in zero-g. This also represents a logical extension of investigations done in Skylab and will provide a more detailed examination of cardiovascular mechanisms operable in zero-g as well as during readaptation to the normogravic environment.

B. Purpose

The purpose of this effort in SMS-II is to develop a space experiment which will measure the time course and magnitude of changes in central blood flow and volume relationships in zero-g, as determined by measurements of pulmonary blood flow (cardiac output).

Subaltern objectives include:

- Testing an integrated system designed to provide a complex array of measurements of cardiopulmonary function during exercise,
- Evaluating the experiment protocol and equipment in an operational environment, and
- Testing the concept that a dedicated minicomputer can be integrated into a payload and shared by several experiments.

C. Participants

1. Number of Crewmen

   All crewmen will participate in this experiment.

2. The TOT will be made up of the PI, PE, Test Control Team, Test Operations Personnel (Science Manager), Data Specialists, and support personnel.

4.7 (continued)

D. Functional Objectives

To determine through performance, possible iterations, and analyses:

- The suitability of experiment hardware with respect to selection, development, and operability, and to optimize hardware packaging.
- The display and recording requirements external to the experiment.
- The crew training requirements.
- The crew procedures.
- The crew and experiment time schedules.

E. Performance Requirements and Conditions

All crewmembers will participate in the experiments. Preflight baseline data will be collected as outlined in paragraph K.1.

Resting pulmonary blood flow only will be measured bihourly on mission day 1, beginning as soon as practicable after orbital insertion and activation of the gas analysis apparatus. For this demonstration, the subjects will be supine for these measurements.

One experimental exercise test will be accomplished on each crewman on each mission day beginning on mission day 2. The approximate timeline for each test is as follows:

- 20 minutes for calibration and instrumentation of subject
- 5 minutes for data collection at rest
- 5 minutes for exercise at 75 W and data collection
- 5 minutes for recovery and data collection

Each test will require the participation of two crewmen, one as the subject and one as the observer.

Personal (nonexperimental) exercise regimens will occupy approximately one hour per participating crewman per day. On an experimental basis, half of the crew will participate in these exercise programs. Details of the regimen for each crewman will be decided between the crewman and the PI's. An exact record of exercise type and duration will be required for each session. Record format is TBD.

F. Environmental Requirements

The normal laboratory environment is satisfactory for performance of this experiment. No specific limitations have been defined at this present time. No interference with other experiments is anticipated.

G. Hardware Requirements

The experiment hardware for the gas/volume analysis rack is shown in figure 4-4. A respiratory mass spectrometer (MS) is located at the top of the rack. This unit is a special modification of the original Skylab configuration to permit breath-by-breath analysis.

Additional flexibility permits the analysis of breath composition waveforms at the mouth, or batch sampling at the exhalation spirometer. A complete control panel is included to operate and monitor the MS. Spirometers for measuring expired and inspired gas volumes are located below the MS control panel. The expiration spirometer is a standard flight configuration M171 spirometer. The inspiration spirometer was specially constructed

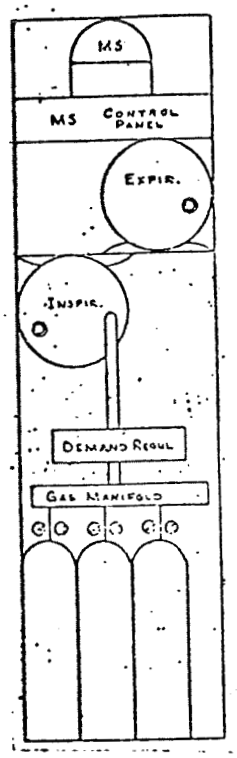


Figure 4-4. Rack Hardware for Gas/Volume Analysis Experiment.

to have a 7-liter capacity like the exhalation spirometer. This important modification permits the use of the spirometers for flow/volume loops without the possibility of cross-contamination of subjects that occurs when one spirometer is employed. The remainder of the rack is devoted to housing experiment gas supply cylinders, regulators, and a special computer switched gas selection manifold. This device permits the computer to select calibration gas mixtures or various breathing mixtures according to their utilization in the experiment protocol.

For this experiment a Collins-type ergometer and a Mini-Gym Isokinetic Exerciser modified to provide for an electrical

4.7 (continued)

output of the measured forces will be used. The ergometer must be located within 10 feet of the gas analysis rack. When not in use, the Mini-Gym will be stowed in the storage rack.

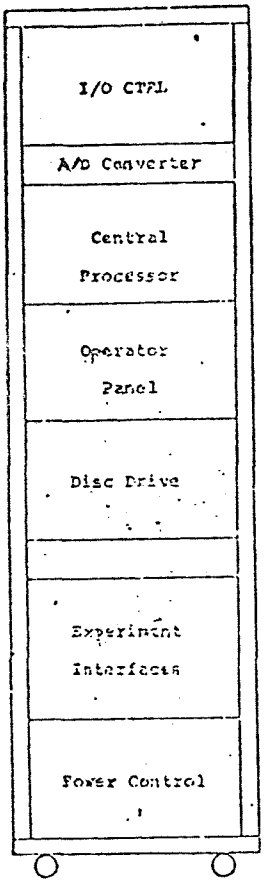


Figure 4-5. Computer Rack.

The computer equipment configuration is shown in figure 4-5. The system includes a central processing unit (CPU) (PDP-8e), disc drive, Analog-to-Digital (A/D) converter, power controller, and operator's panel. Digital input-output (I/O) interfaces will be mounted inside the CPU, and a graphics terminal will be mounted in another rack. Software for this system will provide for data acquisition, analysis, and display for this and other proposed experiments. The operating system will provide controllers for all I/O devices, and provision for experiments which require 24-hour monitoring of experiment signals. Software for other experiments will be stored on the disc, and any one of these can be called and executed by a single key entry on the operator's panel.

The computer will then be dedicated to that experiment until it is completed; however, the computer will continue to provide 24-hour monitoring as required. Data will be acquired via A/D converter and digital I/O, reduced and presented on either a small digital printer or the graphics terminal.

4.7 (continued)

H. System Interface

- No specific location is required for this equipment.
- No specific mounting requirements have been established at the present time.
- Utility Requirements:

Item	Electrical Power: Maximum (W)	Voltage (V)	Frequency (Hz)	Gas Type	Pressure
Ergometer	500	115	60		
Mini-Gym	100	115	60		
Computer Rack	875	115	60		
Gas Analysis Rack	200	115	60		
Storage/CRT Rack	150	115	60		

I. Data Support Requirements

- Preflight - NA
- In-flight - TBD
- Postflight - TBD
- Analysis and Processing Support - TBD
- Data Information

Measurement Information

Equipment Items To Be Used:

- Respirator Mass Spectrometer
- Exhalation and Inhalation Spirometers
- Gas Supply Cylinders
- Collins-type cycle ergometer
- Mini-gym Isometric Exerciser

4.7 (concluded)

J. FDF Requirements

A maintenance and troubleshooting guide will be required, in addition to timelines and Flight Plan procedures.

K. Preflight and Postflight Requirements

1. Preflight

The experiment will require two preflight training sessions in order to familiarize the crew with the equipment and procedures. Additionally, three sessions will be required for collection of preflight baseline data.

2. Postflight

No postflight testing will be required for the demonstration.

L. Reporting

Crew comments and logs will be maintained and will be available to the PI's. A preliminary report will be available at R+21 and a final report at R+60 days.

M. Training

Training requirements for the flight crew and support personnel are TBD.

4.8 SMS II-8. RESPIRATORY PHYSIOLOGY AND PULMONARY FUNCTION

Principal Investigator: C. F. Sawin, Ph. D.
Co-Principal Investigator: A. E. Nicogossian, M.D.
Project Engineer: J. D. Lem

A. Background

This approach to the evaluation of pulmonary function in zero-g is to develop a comprehensive program which will include basic research on adaptive mechanisms while determining the requirements for crew selection and in-flight medical monitoring. This program will represent a logical extension of knowledge gained during recent Skylab investigations which included: (1) in-flight vital capacity measurements, and (2) measurement of maximum sustained minute ventilation (maximum exercise testing) together with evaluation of ventilatory equivalents ($\dot{V}_E/\dot{V}_{O_2}$) during rest and exercise. Although these measurements permitted only gross evaluation of pulmonary function, they were sufficient to show that man can endure a three-month's duration exposure to zero-g without serious pulmonary impairment. However, this exposure included a daily regimen of strenuous physical exercise. Under these favorable conditions, we observed an approximate 10 percent decrease in vital capacity although the crewmen were able to sustain exceptionally high maximum ventilatory rates. It must be remembered that these high ventilatory rates were possible primarily because of the 34.7×10^3 N/m^2 (5 psia) ambient pressure.

It is generally accepted that the integrity and proper function of the body require adequate oxygen delivery to and carbon dioxide removal from the body tissues. Thus, the primary function of the pulmonary system is to arterialize mixed venous blood through elimination of carbon dioxide and addition of oxygen. This is achieved by ventilation which, in turn, is

a function of tidal volume, respiratory frequency, and intra-pulmonary distribution of the respired air. Superimposed upon these gaseous factors are the quantity and distribution of pulmonary blood flow. It is believed that the measurements proposed herein comprise the minimum number necessary to quantitate pulmonary function in zero-g, thereby providing data to support the contention that man could be qualified for space flights of approximately two years' duration.

B. Purpose

The purpose of the SMS-II demonstration is to evolve an experiment which will permit evaluation of pulmonary physiology during weightlessness. If combined with experiments described in sections 4-7 and 4-9, the total instrumentation will provide pulmonary function data along with cardiac output at a variety of exercise levels. For more definitive physiological evaluations the following objectives will be pursued:

- To qualify man for long-duration space flight.
- To document and examine the physiological mechanisms involved as the pulmonary system adapts to weightlessness and readapts to normal gravity upon return to Earth.
- To define preflight and in-flight screening requirements.
- To provide beneficial spin-off from these research efforts in order to improve the quality of pulmonary function evaluation in the normal clinical environment on Earth.

C. Participants

1. Number of Crewmen

All crewmen will participate unless prohibited from exercise, or for other reasons.

2. Test Operations Team

The TOT will be comprised of the PI, PE, Test Control Team,

Mission Crew, Test Operations Personnel (Science Manager and others), Data Specialists, and support personnel.

D. Functional Objectives

To determine through performance, possible iterations, and analyses:

- The suitability of experiment hardware with respect to selection, development, and operability, and to optimize hardware packaging.
- The display and recording requirements external to the experiment.
- The crew training requirements.
- The crew procedures.
- The crew and experiment timelines.

E. Performance Requirements and Conditions

1. Experiment Preparation

   - Activate equipment one hour pretest.
   - Calibrate MS, only 5 minutes will be required.

2. Experiment Operations

   Each subject protocol can be accomplished within 5 to 10 minutes. The protocol should be performed every two hours during the first eight hours of flight (a total of four times), and daily thereafter. Each crewman will be a subject for these measurements.

3. Postoperation Tasks

   Closeout and cleanup include cleaning of mouthpiece/valve assemblies and verifying that appropriate equipment has been returned to the standby mode. This will be performed daily and may require 10 minutes.

4. Maintenance and Calibration

Maintenance will be performed only in the event of a failure. Calibration will precede each data collection period. It will be helpful if the crew is AOS during equipment activation and calibration with appropriate air-to-ground (A/G) voice communications.

F. Environmental Requirements

All tests will be conducted in the Spacelab under comfort conditions usually obtained in any ground-based laboratory.

G. Hardware Requirements

The experiment hardware for the gas/volume analysis is rack-mounted. A respiratory MS is located at the top of the rack. This unit was specially modified from the original Skylab configuration to include an inlet leak designed to permit breath-by-breath analysis and the fabrication of a dual capillary inlet system with electronic switching between capillaries. This additional flexibility permits the analysis of respiratory gas composition at the mouth or batch samples at the exhalation spirometer.

A complete panel is included to operate and monitor the MS. Spirometers for measuring expired and inspired gas volume are located below the MS control panel. The expiration spirometer is a standard flight configuration M171 spirometer. The inspiration spirometer was specially constructed by the PE to have a seven-liter capacity like the exhalation spirometer. This important modification permits the use of the spirometers for flow/volume loops without the possibility of cross-contamination of subjects encountered when only one spirometer is employed.

The computer equipment includes a central processing unit, disc drive, A/D converter, power controller, Tektronix CRT terminal and hard copy device, as well as the PDP-8e operator's panel. Digital I/O interfaces are mounted inside the CPU. System software will provide for data acquisition, analysis, and display. The operating system will provide controllers for all I/O devices. Software for other experiments will be stored on the disc, and any one can be called and executed by a single key entry on the operator's panel. The computer will then be dedicated to that experiment until completion. Data will be acquired via A/D converter and digital I/O, reduced and presented on the graphics terminal.

The equipment status is that of a sophisticated breadboard that employs previously flown hardware together with some laboratory developed units.

H. System Interface

- No specific location is required for this equipment.
- No specific mounting requirements have been established at the present time.
- The grouping will require three racks in contiguity.
- Utility requirements:

Item	Electrical Power Maximum (W)	Voltage (Va.c.)	Frequency (Hz)	Gases Type Pressure
Computer Rack	875	115	60	Aviator Oxygen @ 1.38×10^6 N/m^2 (200 psig) N_2 @ 1.03×10^6 N/m^2 (150 psig) Calibration Gas - 15% O_2 - 5% CO_2 Balance - N_2
Gas Analysis Rack	200	115	60	
Stowage CRT Rack	150	115	60	

4.8 (continued)

I. Data Support Requirements

1. Preflight

None defined.

2. In-flight

Spacelab temperature and pressure.

3. Postflight

Return of disc packs from computer to PI's. Return of flight logs and maintenance and troubleshooting logs.

4. Analysis and Processing Support

None required.

J. FDF Requirements

The following items will be required:

- A timeline of daily activities.
- A maintenance and troubleshooting guide.

Since some equipment is also used with other experiments, access to the respective FDF's will be preferable to duplicate files.

K. Preflight and Postflight Requirements

1. Preflight

Preflight requirements will include assembly of the experiment hardware, installation, checkout, and pretest runs. Training will be initiated in the Pulmonary Laboratory and completed in the DTU. Other requirements are TBD. Prelaunch support is required to move the equipment racks into the building 36 mockup area and to provide all necessary interfaces. A suitable vacuum pump will be required.

2. Postflight

Postflight requirements will include data retrieval and analyses, removal of the hardware and reporting.

L. Reporting

TBD in compliance with total mission requirements. Requirements can probably be met by a preliminary report at R+21 and a final report at R+60 days.

M. Training

Crew training can be accomplished in two four-hour sessions. Baseline data can be obtained during an additional three one-hour sessions.

4.9 SMS II-9. THE EFFECT OF ZERO-G ON THERMOREGULATION

Principal Investigator: *J. M. Waligora*
Co-Principal Investigator: *D. J. Horrigan, Jr.*
Project Engineer: *A. V. Shannon, Jr.*

A. Background

Although heat transfer from the body at different levels of energy expenditure has not been a continuing crucial problem during weightless exposure, engineering optimization has not been possible because of the lack of data on heat transfer coefficients during low-level forced air convection.

B. Purpose

The purpose of this study in SMS-II is to develop a space experiment which will assess the effect of zero-g on the rate of heat transfer from the body under the domain of forced air convection.

Measurements will be made of air temperature, air motion, skin temperature, and skin heat flow. Sweat prints will be made from the skin, and sweat absorption papers will be recovered from sweat capsules. Sweat rate will be determined from body mass measurements.

C. Participants

1. Number of Crewmen

   Two or more. The Mission Specialist (MS) and Payloads Specialist (PS) will participate as subjects.

2. Test Operations Team

   The TOT will be composed of the PI, PE, Test Control Team, Test Operations Team (Science Manager and others), Data Specialists, and support personnel.

4.9 (continued)

D. Functional Objectives

To determine through performance, possible iterations, and analyses:

- The suitability of experiment hardware with respect to selection, development, and operability, and to optimize hardware packaging.
- The display and recording requirements external to the experiment.
- The crew training requirements.
- The crew procedures.
- The crew and experiment timelines.

E. Performance Requirements and Conditions

TBD

F. Environmental Requirements

- Temperature: 22 °C ±2 °C (73 °F ±3 °F)
- Humidity: 4 °C to 16 °C (39 °F to 61 °F) dewpoint (6-14 mm Hg)
- No potential interference with other experiments has been identified

G. Hardware Requirements

1. The hardware to measure convective heat transfer coefficient will consist of a harness of eight heat flow sensors and eight thermistors. Heat flow will be measured from the skin to the environment of known temperature. The air velocity at a fixed distance from each probe 15 cm (6 in.) will be measured at the beginning and the end of each test period. The hardware for measurement of evaporative heat transfer will consist of the skin temperature sensors, a scale simulating the in-flight Body Mass Measurement Device (BMMD), the air velocity measurement device, a bicycle ergometer,

sweat capsules, and iodine sweat print papers and equipment. If complete data are to be assessed online, a stereoscopic microscope to count sweat gland indications on sweat prints will be required. The sweat prints could be returned and counted postflight. An analytical scale will be required to measure capsule sweat. The sweat containers could be returned and weighed postflight. The equipment definition is in conceptual stage; the components of the electronic system, however, are available as off-the-shelf items.

2. Linearized interchangeable thermistors and a signal conditioner are available from Yellow Springs Instrument Company (Yellow Springs, Ohio). It is anticipated that a Digiteck Scanner (M636) (Dayton, Ohio) will multiplex thermistor signals from and through the signal conditioner and then to a Digiteck panel meter for digital display and A/D conversion. A digital 8-4-2 BCD output will be available to the computer.

   The heat flow sensors are available from Thermonetics Corporation (San Diego, California). The millivolt signal from these devices will be scanned with the Digiteck scanner, amplified and displayed on a digital panel meter with a digital output. Both an analog and a digital output from the heat flow sensors will be available to the computer.

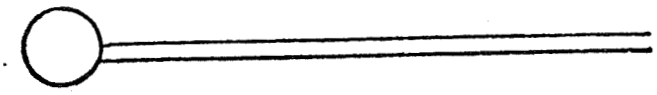
   The air flow device is battery powered and is available from the PI.

   The sweat gland printing equipment and the sweat capsules to be used are of types that have been used by the PI and they will be fabricated in-house.

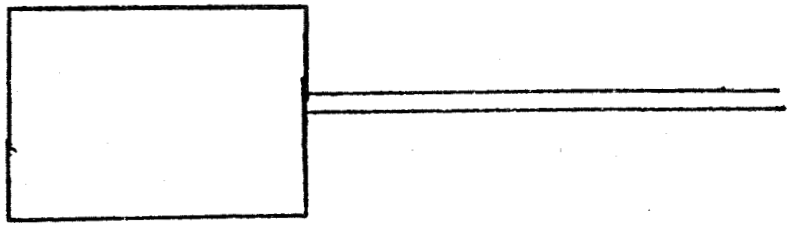
4.9 (continued)

Specific requirements for these items are as follows:

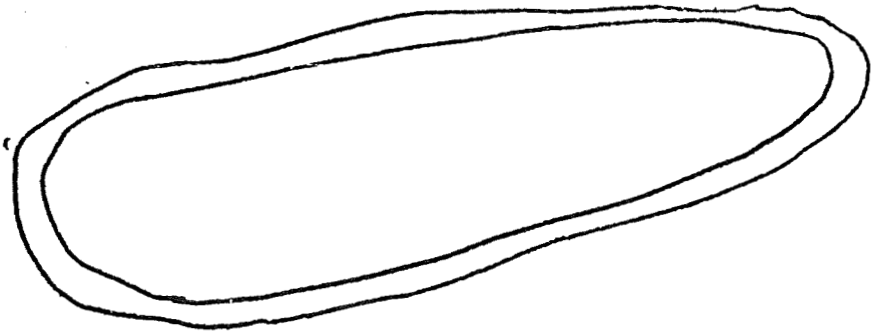
Skin temperature sensor (8 required).
Weight: approximately 224 g (8 oz).



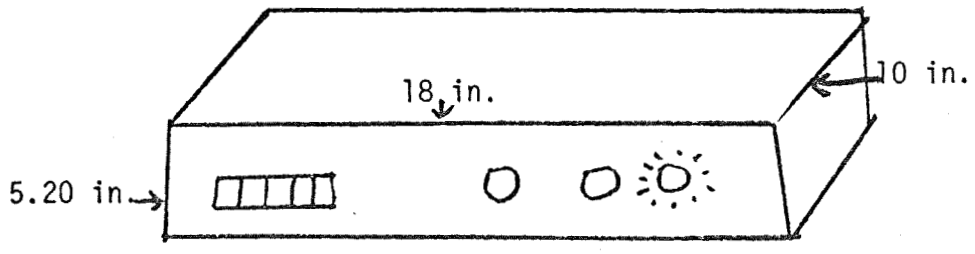
Heat flow sensor (8 required).
Weight: approximately 224 g (8 oz).



Elastic bands with pockets to hold sensors in place (8 required).
Weight: approximately 224 g (8 oz).



Scanner for both thermistors and heat flow probes (1 required).
Weight: approximately 4.0 kg (9 lb).



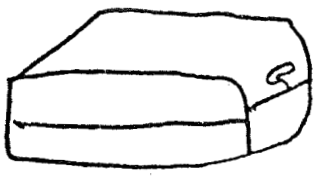
4.9 (continued)

Thermistor signal conditioner - Dimensions:
5.6 cm x13.1 cm x18.9 cm (2.25 in. x5.25 in. x6.75 in.).
Weight: 0.90 kg (2 lb).

Heat flow amplifier (1 required).
Weight: 0.90 kg (2 lb).
Dimensions: TBD

Digital panel meter (2 required).
Weight: 0.45 kg (1 lb).
Dimensions: 8.8 cm x10 cm x3.5 cm (3.5 in. x4 in. x1.8 in.).

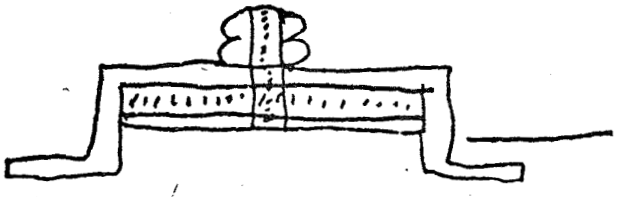
Air motion sensor (4 required).
Weight: 4.5 kg (10 lb).
Dimensions: 26.9 cm x24.4 cm x10.9 cm
(10.75 in. x9.75 in. x4.375 in.)



4.9 (continued)

Sweat Capsule (1 required)

Weight: TBD



Sweat Print Equipment.

Lucite Cylinder (1 ea).

Weight: 5.6 g (2 oz).

- Sweat absorption collection papers 3.8 cm (1.5 in.) circle cut (30 required).
  Weight: 5.6 g (2 oz).
- Sweat print papers 3.8 cm (1.5 in.) circle cut (50 required).
  Weight: TBD
- Airtight bottles for sweat print papers and sweat samples (5 required).
  Weight: 0.5 kg (1 lb) (5 bottles).
- Grid stamp and stamp pad (1 ea).
  Weight: 5.6 g (2 oz).

4.9 (continued)

H. System Interface

- Equipment will be located near a work station and near the ergometer.
- The electronics will be rack-mounted. The sweat print and collection equipment will be located in a drawer
- Utilities:

Item	Electrical Power Maximum (W)	Voltage (V)	Frequency (Hz)
Thermistor signal conditioner	10	115 a.c.	60
Heat flow amplifier	TBD	115 a.c.	60
Scanner	10	115 a.c.	60
Digital panel meters	4	115 a.c.	60
Air motion meter	Batteries	14 d.c.	-

I. Data Support Requirements

1. Preflight - PDP8e

2. In-flight - PDP8e

   Spacecraft temperature and humidity measurements. Photographic documentation of sheeting of sweat.

3. Postflight

   Return of sweat samples.

4. Measurement Information

   Equipment items used:

   - Temperature sensors
   - Heat flux sensors
   - Air motion sensor

Data Measurements

Instructions: State the expected data measurement characteristics in the following format where applicable. Include additional or different information.

Parameter To Be Measured	Temperature		Rate of Heat Flow		Velocity	
Expected Values of Parameter	°C	(°F)	J/m^2	Btu/ft^2)	m/min	ft/min
Average	23-35	(73-93)	$2.6x10^4/0.09$	(25)	9	30
Range	21-38	(70-100)	$1.1x10^4$ to $4.2x10^5/0.09$	(10-40)	3 to 21	10 to 70
Measurement Characteristics						
Times/Day	← 12/mission →					
Duration of each	a 1-min channel scan each 5 min				8 measurements	
Total number in mission	← 450/channel →				5-second measurement before and after each run	
Sample rate	← scan/5 min →				108	
Output Signal of Instrument	Digital and Analog				None	
Frequency range, low to high	Low		Low		Low	
Amplitude range	10 mV/°C		0 to 5 mV			
Instrument resolution (% total scales)	1		5		5	
Output Requirements						
No. of channels	10		8		1	
Sampling rate (s/channel)	4				one 8-point manual scan before and after each test.	
	1-min scans at 5-min intervals					
Telemetry	None					
Recorder	None					
Time Identification Method						
Spacecraft clock or other	← Spacecraft or computer →					

J. FDF Requirements

Detailed procedures, checklists, and a Flight Plan will be required. A system maintenance and troubleshooting guide will be included in the FDF.

K. Preflight, In-flight and Postflight Requirements

1. Preflight

a. Crew training

The crew must be trained in application of sensors, operation of instrumentation, sweat collection, and sweat print technique. The required training is estimated as three one-hour periods per crewman.

b. Prelaunch support

- Store fresh expendables: batteries for air motion sensor, and sweat print paper.
- Obtain tare weights of sweat collection bottles, unless a Small Mass Measurement Device (SMMD) is available on board.

2. In-flight

a. The experiment will consist of three Detailed Test Objectives (DTO's). Each will repeat twice on each subject for a total of 12 test operations.

b. DTO 1 and DTO 2 will be measurement of the convective heat transfer coefficient at a work station and on the ergometer at low work rates.

- Experiment preparation will consist of the following:
  - Don shorts and instrumentation (10-15 min),
  - Activate the instruments,
  - Select and set up the computer program,
  - Measure the airflow rate at eight locations, and
  - Feed the data into the computer.
- During the 30-minute test, the subject will engage in the usual console activities or will work at a moderately high workload (pedaling at a lower power setting) on the ergometer. At the end of

12 minutes he will stop and the observer will:

- Obtain a body weight,
- Remove absorptive sweat collection papers from unventilated sweat capsule,
- Make sweat prints at an exposed location and from the two sweat capsules, and
- Reload the sweat collection capsule from a fresh bottle.

This sequence will be repeated at 27 minutes, 42 minutes and 58 minutes. At 60 minutes, air motion measurements will be repeated and results entered into the computer.

c. DTO 3 will measure the effect of zero-g on evaporative heat loss.

° Experiment preparation will consist of the following:

- Don skin temperature sensors.
- Don sweat capsules, ventilated and unventilated.
- Remove two of three sweat absorption papers with gloved hands and place in the unventilated sweat capsule. Seal the capsule and bottle containing one remaining paper. Weigh three sweat collection bottles prior to each performance of this DTO if an SMMD is available on board.
- Select and set up the computer program
- Enter air motion measurements into the computer.
- Measure body weight.

d. Post-test Operations

° Remove, clean, and stow the instrument.

° Weigh the three sweat collection bottles if an SMMD is aboard. If not, stow them.

- Stamp the sweat print with a 2 cm^2 grid and, if a stereoscopic microscope is aboard, count the active sweat glands; if not, stow the prints.
- Stow the data.

Routine maintenance: Clean sweat capsules after each use.

3. Postflight

a. Obtain sweat weights and print counts from the returned samples if an SMMD and a stereoscopic microscope are not available in-flight.

b. Leach the sweat from the papers with a fixed quantity of water and analyze.

c. Remove the sensors and stow them and the data.

L. Reporting

A preliminary report will be due R+21 and a final report at R+60 days.

M. Training

See paragraph K, Preflight, In-flight and Postflight Requirements.

4.10 SMS II-10. VESTIBULAR FUNCTION

Principal Investigator: M. F. Reschke, Ph. D
Co-Principal Investigator: J. L. Homick, Ph. D.
Project Engineer: R. G. Thirolf

A. Background

Knowledge of vestibular system behavior is regarded as indispensable to generate methods to prevent disabling responses in individuals exposed to the weightless conditions of orbital and space missions. It has fundamental significance for the understanding of normal function and for developing a therapeutic approach to clinical problems.

B. Purpose

The purpose of this study in SMS-II is to develop a space experiment which will measure, by electronystagmography (ENG), the response of the human vestibular system to variable angular accelerations and provide inputs to a transfer function model of the semicircular canal neural system with particular application to otolith behavior following transition into weightlessness.

C. Participants

1. Number of Crewmen

   Two crewmen are required, one to serve as a subject and the other to serve as observer. Additional participation will increase the data base but will not otherwise further development of the experiment.

2. Test Operations Team

   The TOT will be composed of the PI, PE, Test Control Team, Mission Crew, Test Operations Personnel (Science Manager and others), Data Specialists, and support personnel.

D. Functional Objectives

To determine through performance, possible iterations, and analyses:

- The use of electronystagmography to obtain values that can be applied to a system transfer model of the semicircular canal neural system as a means of determining possible alterations in canal input which may be modified via otolith behavior following transition into weightlessness.
- The expansion of the dynamic testing range of the torsion chair.
- The feasibility of utilizing off-the-shelf hardware as well as the possibility of sharing equipment to develop a space flight system which will permit precise control of vestibular stimulation, and to record physiological parameters associated with the vestibular system.
- The suitability of experiment hardware with respect to concept applicability, selection, development, and operability, and to optimize hardware packaging.

E. Performance Requirements and Conditions

1. Experiment Preparation

Two crewmen are required for experiment preparation, one as experimenter/observer and the other as the subject. Instrument setup, calibration, and electrode placement will be performed by the observer. Approximate time to complete these tasks is thirty minutes. Following the placement of the electrodes, the subject will wear red dark adaptation goggles for 20 minutes. During this period the observer will complete instrument verification and calibration.

2. Experiment Operations

Following the 20-minute red adaptation period, both crewmen will be required to participate in the experiment.

Total estimated time for completion is 85 minutes. The following steps will be followed:

- The subject will sit in the torsion chair, and the observer will initiate eye calibration procedures, start time, and set the tape recorder to the record mode. Five minutes are required for this operation.
- The observer will replace the subject's red goggles with light-tight goggles. One minute is required.
- The observer will then power the chair allowing for five complete oscillations at 0.1 and 0.7 Hz, three at 0.5 and 0.3 Hz, and two oscillations at 0.01 Hz. The procedure will be repeated twice for each frequency allowing for a 90-second rest between all frequencies tested. It is estimated that approximately 50 minutes are required for this step.

3. Postoperation Tasks

Following the last set of oscillations, the subject may remove the goggles and participate in powering down the equipment. At this time, the observer may remove and clean the surface electrodes. Time, including that required to debrief the subject, is estimated to be five minutes.

F. Environmental Requirements

- Need low light levels during conduct of the experiment.
- Avoid directional thermal, light, noise, or airflow cues.
- Keep sensory-sensitive thermal, light, noise, and airflow conditions near cabin average; prevent sudden change.
- Avoid extraneous air/ground voice communication except between the PI and experiment observer/conductor.
- Avoid potential electromagnetic interference (EMI) during the checkout phase.

4.10 (continued)

G. Hardware Requirements

The following equipment items are required for the performance of this experiment.

- Preamplifier/amplifier - This amplifier set is an off-the-shelf item from the Grass Instrument Company (Quincy, MA). It can be used to record the ENG potentials in either a d.c. or a.c. mode. Controls are available for easy manipulation by the experimenter.
- Power Supply - The power supply is an off-the-shelf item from the Grass Instrument Company. It is to be used to power the preamplifier/amplifier for recording the ENG potentials.
- Oscilloscope - This oscilloscope is an off-the-shelf item from the Tektronix Company, Inc. (Houston, TX). It will be employed to calibrate the ENG and torsion chair system that is being recorded on the frequency modulation (FM) tape system.
- Electrodes - Three electrodes will be used to record the ENG potentials. The electrodes are off-the-shelf silver/silver chloride disk electrodes, from the Beckman Instrument Company.
- Dark Adaptation Goggles - Red lens dark adaptation goggles will be used to increase the subject's sensitivity to light and control initial status. They are an off-the-shelf item from the American Optical Company.
- Recorder - The FM tape system will be a common equipment item aboard the spacecraft module. The type is TBD.
- Electrode Application Kit - The application kit contains items for attaching, removing, and cleaning the recording electrodes, *i.e.*:
  - electrode collars
  - sterile wipes

- alcohol wipes
- electrode paste
- paste applicator

° Torsion Chair - The Skylab M131 RLC has been modified to oscillate in a harmonic manner at selectable frequencies and fixed amplitudes.

H. System Interface

° The onboard electronics will be installed in standard 47.5 cm (19 in.) racks.

° Utilities required:

Item	Electrical Power Peak (W)	Voltage (V)	Frequency (Hz)
Chair Power Supply	1150	115	60
Miscellaneous Electronics	450	115	60

° Ground tape recorder equipment is required.

° Interconnecting cabling is required between experiment rack and tape recorders.

° A PI observation station is required where voice, video and real-time data can be observed.

° It is required that access be available for the retrieval of strip chart recordings postflight and, if an on board tape recorder is available, the removal of the tapes. It is also required that postflight recalibration of the equipment be made possible.

° Voice communication with crew is required during all station passes, while the Vestibular Function Experiment is in progress.

° Video observation of the experiment is required during all station passes.

4.10 (continued)

I. Data Support Requirements

In-flight

1. Data will be telemetered to the ground during station passes for all experimental runs. The following specific requirements have been identified at this time with others still to be determined:

   - Presentation of oscilloscope or strip chart real-time data, including eye position, chair position, and time.
   - Presentation of video and audio equipment.
   - Proper room temperature, amount of lighting, and elimination of background noise, if possible.

2. Measurement Information

   - Equipment items used
     - Amplifier 1 (electrode)
     - Torsion chair
     - Time Code Generator

Data Measurements

Instructions: State the expected data measurement characteristics in the following format where applicable. Include additional or different information.

Parameters To Be Measured	ENG	Chair Velocity	Time
Expected Values of Parameter	mV	Radians	
Average value	3	0	
Range	0.5-6	-1.57 to 1.57	
Measurement Characteristics			
Times/Day	1	1	1
Duration of each	TBD	TBD	TBD
Total number in mission	7	7	7
Sample rate	175 Hz	50 Hz	
Output Signal of Eye and Amplifier			
Type	Analog	Analog	Bilevels
Frequency range: low to high (Hz)	d.c. to 10	d.c. to 1	.IRIG*
Amplitude range instrument resolution (% Total Scale)	±1VRMS	±1VRMS	SLOW CODE
Readout Requirements			
No. of channels	4		
Sampling rate (times/s)	Analog onboard	175 (real-time)	
Telemetry	Real-time		
Recorder (returned tapes)	yes		
Time Identification (Spacecraft clock or other)			
Method	Other		

*IRIG Interrange Instrumentation Group
1VRMS Volts Root Mean Square

4.10 (continued)

J. FDF Requirements

The following will be required:

- A timeline of daily activities.
- Detailed procedures and checklists.
- A maintenance and troubleshooting guide.

K. Preflight and Postflight Requirements

1. Preflight

Prelaunch support, prior to the actual demonstration/ training is to consist of the following:

- Perform pre-installation tests on each of the electronic equipment units; if these units are found to be acceptable, they will be mounted in the desired mockup location.
- Mount the recording hardware - include all wiring and interfaces to make the equipment operational. Include hookup of ground support equipment outside the test unit. Locate and place the torsion chair in a "to be specified" location within the test unit.
- Provide transportation of the necessary equipment from the JSC Neurophysiology Laboratory to the test unit for installation there.

2. Postflight

The following data requirements have been identified at this time for return to JSC:

- All tape recorded data for analysis in the laboratory, if an on board analog tape machine is available.
- All strip chart recordings of the ENG data obtained in-flight.
- All written logs.

- Voice-recorded comments relating to the Vestibular Function Experiment which will be furnished to the PI.
- Experiment equipment which will be disassembled and removed to the Neurophysiology Laboratory.

L. Reporting

TBD in compliance with total mission requirements. Requirements can probably be met by a preliminary report at R+21 and a final report at R+60 days.

M. Training

Crew training will begin (at a now unspecified time) before the demonstration, and will require brief instructions over a short period of time. Estimation of this time is approximately five one-hour sessions. More specifically, the training will require that the crewmen visit the JSC Neurophysiology Laboratory (or the DTU, if the equipment is installed prior to training). These visits will be:

- To indoctrinate the crewmen in the experiment concept,
- To indoctrinate the crewmen to act as experimenters,
- To obtain control measurements for the "subject" crewmen, and
- To perform baseline testing of the ENG response to sinusoidal angular acceleration and perhaps other related vestibular functions.

Identical equipment will be used in training as that employed for the demonstrations.

Training of support personnel and indoctrination of test control personnel are TBD.

4.11 SMS II-11. ACUTE FLUID AND ELECTROLYTE METABOLISM RESPONSES TO SPACE FLIGHT

Principal Investigator: C. S. Leach, Ph. D.
Project Engineer: R. G. Thirolf

A. Background

Effects of weightlessness upon calcium and electrolyte metabolism have been suggested from a variety of experimental approaches that have been used in the Apollo and Skylab programs. In addition, alterations in body fluid distribution and composition have been a relatively consistent manifestation of space flight. However, the sequence of responses relating to these alterations has been elusive in character, due to a lack of in-flight analytical capability to measure acute changes occurring in weightlessness and the operational demands on the crewmen which prevented them from collecting early data.

Dietary intake, bone resorption, calcium excretion, exercise, and altered endocrine factors have been suggested to account for responses in calcium balance during previous flights.

Analyses of biochemical and endocrine compounds from samples obtained during previous missions are suggestive of very acute responses occurring soon after insertion into a weightless environment. Various aspects of body fluid metabolism and composition have been associated with these responses.

In-flight analytical capability for several of these parameters now appears feasible and such systems may have a potential for in-flight experimentation in Spacelab.

4.11 (continued)

B. Purpose

The purpose of this study for SMS-II is to develop a space experiment which will enable identification of acute changes in systemic physiological factors that occur upon introduction into zero gravity environment, with particular reference to fluid and electrolyte metabolism.

C. Participants

1. Number of Crewmen

The number of crewmen will include the Mission and Payloads Specialists who will participate as subjects, and will also collect, analyze, and preserve samples. Baseline data will be required from each for 14 days prior to mission simulation and until restabilized postmission.

2. Test Operations Team

The TOT will include the PI, PE, Test Control Team, Mission Crew, Test Operations Personnel (Science Manager and others), Data Specialists, and support personnel.

D. Functional Objectives

To determine through performance, possible iterations, and analyses:

- The suitability of experiment hardware with respect to selection, development, and operability, and to optimize hardware packaging.
- The display and recording requirements external to the experiment.
- The crew training requirements.
- The crew procedures.
- The crew and experiment timelines.

4.11 (continued)

E. Performance Requirements and Conditions

1. Blood sampling will follow the following schedule:

   - Preflight on T-14, T-7, T-1 days.
   - In-flight on days 1 and 4.
   - Postflight on days 1 and 3.

   Early morning samples of plasma will be collected in fasting condition and frozen for postflight analysis of parathyroid hormone. Urine samples will be collected on a void-by-void basis for each day when blood is drawn. In addition, in-flight measurement and analyses of each sample will be made for concentration of calcium, sodium, potassium, chloride, and creatinine, and pH and pCO_2. Levels of selected endocrine parameters will be determined postflight in frozen samples derived from these in-flight collections.

   The concentrations of the constituents in blood, the quality excreted in the urine, and the temporal pattern of alterations from preflight levels will be examined and correlated with respect to physiologic mechanisms known to produce these responses. The temporal pattern may be a significant indicator of these responses so in-flight analysis is important to reduce possible error as a result of storage procedures. Samples collected postflight will be used to monitor the pattern of return to preflight values, which will augment the validity of scientific conclusions resulting from in-flight responses.

   The blood and urine samples collected in accordance with the experimental design will be analyzed in-flight for electrolytes using an automated ion-selective electrode system, and creatinine total protein and phosphorus using the GØ Analyzer. A portion of each sample will be stored as frozen serum or

urine and return for postflight analysis of related endocrine factors. Total body water will be determined the first day in-flight using ^3H_2O. The samples will be returned for post-flight analysis. It will be necessary to log H_2O intake and urine excretion for the first 48 hours in-flight and postflight.

The data will be analyzed to determine the effect of weightlessness on creatinine clearance, excretion of electrolyte and water after one and four days of space flight and after recovery. The hormones ADH and aldosterone will be measured to document their effects or immediate changes. Measurement of total body water the first day in-flight will document the loss which has been suggested to be present.

2. Preflight Preparation

Activate the Fast Analyzer in the standby mode. Clean, or dispose of, the rotor.

3. In-flight Usage

Dispose of the used blood collecting equipment properly. Prior to the operation of the experimental hardware each day, a standard solution will be analyzed as a check on instrument performance.

Experiment operations will consist of blood and urine sample collections (the exact details and schedule of which are to be developed), the subsequent in-flight analyses of these samples, and storage of specimens for post-flight analyses.

F. Environmental Requirements

Crewmen will need to avoid environmental and other influences which could grossly disrupt fluid, mineral, and hormone balance

prior to the simulation and immediately thereafter. The DTU will need to be maintained at a level for crew comfort, and no thermal perturbations above perhaps 28 °C (82 °F) can be tolerated while analyzers are operating, because of an inability to regulate reagent and electrode temperatures in a warm environment.

G. Hardware Requirements

° Fast Analyzer

The miniature Fast Analyzer is a compact photometric instrument occupying only 0.09 m^2 (a square foot) of bench space and weighing only 13.5 kg (30 lb). Its primary function is to spin a 17-cuvet rotor at speeds of up to 5000 r/m (normal operating speed is 700 r/m), through a stationary optical system. The optical system consists of a quartz-iodine tungsten light source located in a movable housing mounted above the rotor, interference filters, and a miniature photomultiplier (PM) tube. The six interference filters are contained in a movable filter wheel mounted just under the rotor housing. These filters are positioned manually in the light path by means of the filter selector switch. The basic raw data generated by spinning cuvets through the optical system consists of a synchronized series of voltage signals which can be displayed on an oscilloscope and stored and processed by means of an on-line computer. The performance of the Fast Analyzer has been defined by evaluation of the instrument both at JSC and Oak Ridge National Laboratories, as well as during usage in the first DTU. Expected performance is within the limits of clinical instrumentation.

° Ion Selective Electrodes

This hardware consists of an Automated Potentiometric Electrolyte Analysis System (APEAS). The system has four basic components:

- A fluid transport unit (FTU) to accept and deliver the sample to the electrode sensors and subsequent waste bag.
- An electronics unit (EU) to amplify the output of the electrode sensors and channel impulses to and from the FTU.
- A controlled-processor to direct the EU control of the FTU and process the amplified output of the FTU.
- A teletype to print data and diagnostic output from the controller-processor and enable executive input to the system.

The performance of this system, based upon current studies, is expected to be of sufficient accuracy for the purpose of this test. A standard error of less than five percent of the mean value is expected for most parameters.

H. System Interface

The Fast Analyzer and the oscilloscope have no requirements for a specific location within the Spacelab. The location of the computer and teletype has yet to be determined.

° Fast Analyzer - hard-mounted to rack
° Oscilloscope - position and location near the Fast Analyzer
° Computer - to be developed
° Teletype - to be developed

4.11 (continued)

Utilities are as follows:

Item	Electrical Power Maximum (W)	Voltage (V)	Frequency (Hz)
Fast Analyzer	2.5	115	60
Oscilloscope	2	115	60
Computer	720	115±5	60
Ion Selective Electrode System	TBD	TBD	TBD
Teletype	TBD	TBD	TBD

The ion selective electrode system may be located anywhere within the test facility that will allow frontal access to the FTU and EU.

The FTU should be mounted approximately 125 cm (50 in.) above the floor level.

Support equipment consists of a centrifuge to separate cellular materials from blood samples, a freezer to preserve samples for postflight analysis, and a refrigerator.

All control panels and displays must be located in a presenting configuration that is readily visible from a single vantage and operation point for the crewmen.

The PI should have direct or minimally indirect uplink capability during the in-flight conduct of this demonstration for consultation on problems of technique and/or maintenance, should they arise.

I. Data Support Requirements

Data generated by the automated analyzers will be printed out external to the DTU.

Postflight data support requirements consist of logs of the instrument operation and return of the unanalyzed blood and urine specimens that have been maintained in a frozen state.

Analyses and data processing support requirements can be met by data analyses systems available in the biochemistry and endocrine laboratories.

J. FDF Requirements

Daily timelines, detailed procedures, checklists, and maintenance and troubleshooting guides will be required.

K. Preflight and Postflight Requirements

1. Preflight

Prior to flight, baseline control values for each crewmember need to be established by analyses of samples collected on several of the 14 days preceding launch. Fasting conditions and early morning collection times should be maintained to ensure the maximum relevance of these control values.

2. Postflight

The PI and/or PE will require access into the DTU to obtain the frozen specimens for postflight analysis and to evaluate the condition of the instruments.

Blood and urine samples early in the postflight period are required to monitor acute responses resulting from reentry into a normal gravitational environment.

L. Reporting

TBD in compliance with total mission requirements. Requirements can probably be met by a preliminary report at R+21 and a final report at R+60 days.

4.11 (concluded)

M. Training

Crewmen will be thoroughly trained in principles and techniques of operation, use, and maintenance of the total on board system. Crew training is expected to require one week for the GØ Analyzer and two weeks in the operation of the APEAS. Crewmen will require familiarization with the DTU installation prior to the flight phase. Once equipment has been installed and checked out by the PI and/or PE, no further prelaunch support will be required.

4.12 SMS II-12. THE STUDY OF SKELETAL MUSCLE FUNCTION IN SPACE FLIGHT

Principal Investigator: E. V. LaFevers, Ph. D.
Co-Principal Investigators: A. E. Nicogossian, M.D.; J. L. Baker
Project Engineer: C. R. Booher

A. Background

Skylab provided the first opportunity to study the effects of long-duration weightlessness on human skeletal muscle function. The results of these assessments provided ample evidence that normal muscle function is significantly altered by periods of weightlessness of 28 days or more. This conclusion is supported by a number of physiological and biochemical body changes that occurred in the Skylab mission; changes which ground-based laboratory studies have shown to be related to abnormal muscle function.

For example, in the Skylab crewmen, considerable muscle atrophy occurred, and muscle tension capabilities decreased, as did the time course of the Achilles Tendon Reflex which reflects a state of hyperreflexia. The electromyogram (EMG) spectral characteristics showed states of muscle hyperexcitability and increased fatigability which only gradually returned to baseline values. Losses in body calcium and potassium occurred also, as well as alterations in enzymes related to muscle function, *i.e.*, adenosine triphosphatase, hexokinase, pyruvate kinase, and acetylcholinesterase. These changes suggest potential trophic influences in muscle function resulting from effects of weightlessness on the body system.

The literature abounds with ground-based laboratory studies to determine the effects of disuse on skeletal muscle. The results of skeletal muscle immobilization, by joint pinning, plaster cast encasement, *et cetera*, have been varied and

sometimes inconsistent. A principal reason for the relative ineffectiveness of these immobilization techniques lies in achieving near-absolute disuse conditions without concomitant ever present gravity forces on the body-total. Likewise, disuse studies predicated on nerve cutting or tendon severing suffer the disadvantage of inflicting severe trauma on the neuromusclar system which transcends the effects of muscle disuse and undoubtedly confuses the real effect of disuse.

The muscle changes observed in the Skylab crewmen were of the same general type as observed in ground-based laboratory studies of muscle function, *i.e.*, muscle wasting, decreased tension capabilities, and increased fatigability. However, one muscle change observed in the Skylab crewmen has not been found to any significant degree in laboratory studies of muscle disuse, that is, the speeding of the contraction times of a "fast" muscle. Previous studies have shown this change to be characteristic of "slow" muscles, such as the soleus, but speeding in the gastrocnemius, a "fast" muscle, for example, has not been demonstrated.

Obviously, an important distinction in the Skylab results, and one that may provide a key to the apparent "speeding" of fast muscle and therefore heightened fatigability, is the biomedical alterations that occurred in the crewmen. These changes included body mineral content and enzyme levels, both of which have been shown to be instrumental to the efficiency of neuromuscular transmission.

The fatigability of striate muscle is dependent upon the type of fibers that predominate in the muscle. Studies have generally shown that "white" fibers are dominant in "fast" or phasic muscles and"red" fibers are most prevalent in "slow" or tonic muscles.

"Fast" muscles, such as the tibialis anterior, gastrocnemius, biceps brachii, *et cetera*, ones that are used to provide powerful but relatively short-lived contractions, are considerably more fatigable than the slower tonic muscles used to maintain posture. Thus, the frequency at which a muscle functions is related to its susceptibility to fatigue; the higher the frequency of muscle contraction, the greater the fatigability. This special characteristic of striate muscle could adversely affect the very long-duration space missions of one to three years, because Skylab data have shown a predisposition of the neuromuscular system to stimulus hypersensitivity when subjected to space flight disuse. And more important, perhaps, may be the consequences of increased fatigability in the tonic, postural muscles normally relied upon for endurance. Thus, knowledge about neuromuscular changes resulting from skeletal muscle disuse in a null gravity environment will be materially enhanced by carefully selected studies, both human and animal, conducted during short- and long-duration space missions.

B. Purpose

The purpose of this in-flight experiment is to assess changes that occur early in a period of disuse, *e.g.*, the first five to seven days. This study in SMS-II will develop a space experiment to identify and describe muscle dysfunction characteristics and to identify consequences resulting from space flight disuse for the purpose of providing useful information for work design, crewman health and safety, and in addition, to extend the existing knowledge about the potentially debilitating effects of skeletal muscle disuse. The relationship between muscle capability, in terms of strength or tension, fatigability, and EMG characteristics of muscle electrical activity will be investigated, as well as the differential effects of space flight disuse on "fast" and "slow" muscles.

4.12 (continued)

C. Participants

1. Number of Crewmen

Two or more crewmen will be required.

2. Test Operations Team

The TOT will include the PI, PE, Test Control Team, Mission Crew, Test Operations Personnel (Science Manager and others), Data Specialists, and support personnel.

D. Functional Objectives

The functional objectives are:

- To develop concepts for in-flight measurement of muscle function using noninvasive techniques with previously used ground-based hardware.
- To determine through performance, possible iterations, and analyses:
  - The suitability of experiment hardware with respect to selection, development, and operability, and to optimize hardware packaging.
  - The display and recording requirements external to the experiment.
  - The crew training requirements.
  - The crew procedures.
  - The crew and experiment timelines.
- To collect baseline data.

E. Performance Requirements and Conditions

The experiment protocol will include preflight, in-flight, and postflight EMG measurements. Muscular stress will be provided by standardized isometric contraction tasks to stress appropriate upper and lower torso muscles. To determine the EMG characteristics of both "fast" and "slow" muscles surface-type electrodes and a series of isometric stresses will be used.

4.12 (continued)

1. The procedure will include:

   - Calibration of test equipment,
   - Attaching the electrodes to the muscles,
   - Activating the system and performing the stress ability, and
   - Recording the data.

   The procedure will require approximately 15 to 20 minutes per crewman each time it is conducted.

   Muscle measurements will include the EMG and force exerted. Time will be an independent variable in the evaluation of muscle fatigability. Requirements for instrument output are depicted as follows:

2. Measurement Information

   - EMG Measurement System
   - Skeletal Muscle Stress Apparatus (SMSA)

Data Measurements

Instructions: *State the expected data measurement characteristics in the following format where applicable. Include additional or different information.*

Parameter To Be Measured		Electromyogram	SMSA Instrumentation Newton (lbf)
Output Signal of Instrument	Type	Analog	Analog
	Frequency Range, Low	5-400 Hz	Varying d.c.
	Amplitude Range (V)	-5, +5	-5, +5
	Instrument Resolution (% Total Scale)		
Readout Requirements	No. of channels	2	1
	Telemetry	Delayed	Delayed
	Recorder	Delayed	Delayed
Time Identification Method	(Spacecraft Clock or other)	G.m.t. on Data Tapes	

Note: A four-channel Tannenburg Tape Recorder with inputs compatible with the above instrumentation outputs is available in the Building 7-A Cardiovascular Laboratory for utilization with this experiment.

4.12 (continued)

3. Observe the following conditions.

   - Perform experiment on a particular crewman at the same time of day, *i.e.*, morning or afternoon.
   - Perform experiment at least 30 minutes after a meal.
   - Follow experiment run by, but do not precede it with, strenuous exercise.
   - Conduct experiment on two crewmen.

4. Experiment preparation elapsed time - 45 minutes.

   - Unstow, if stowed, and set up the SMSA.
   - Activate power to EMG measuring system - check connections to magnetic tape and strip chart recorders.
   - Calibrate load cell on SMSA - record on magnetic tape and monitor on strip chart.
   - Calibrate signal (1 mV = 3 volts) through EMG system - record on magnetic tape and monitor on strip chart.
   - Prepare electrodes for application to skin.
   - Prepare skin areas for application of electrodes.
   - Apply electrodes to brachial biceps, brachioradialis, gastrocnemius, and soleus muscles.
   - Assume seated position in SMSA and connect lap and chest restraints.
   - Connect electrodes to instrumentation harness - verify muscle signal output to tape recorder.

5. Experiment operations elapsed time - 40 minutes.

   Preliminary

   - Secure leg in the SMSA.
   - Perform two MVC's.
   - Perform muscle electrical efficiency protocol.
   - Perform 90 s fatigability test at 50 percent MVC.
   - Secure arm in the SMSA.
   - Perform two MVC's.
   - Perform muscle electrical efficiency protocol.
   - Perform 60 s fatigability test at 40 percent MVC.

6. Postoperation task elapsed time - 5 minutes.

   - Remove electrodes from skin areas and from instrumentation harness. Hand out used electrodes.
   - Deactivate power to EMG equipment.
   - Stow SMSA (if necessary).

Real-time voice communication with crew is required during experiment runs.

Strip chart recording of experiment data for PI monitoring is required on ground during experiment runs.

7. Muscle Efficiency Protocol

Time (minutes) (-) 0:05	Ready Signal	Activate Recorder
0:00	Crewman apply 10% MVC	
0:10	Rest	
0:35	Ready signal	
0:40	Apply 20% MVC	
0:50	Rest	
1:15	Ready signal	
1:20	Apply 30% MVC	
1:30	Rest	
1:55	Ready signal	
2:00	Apply 40% MVC	
2:10	Rest	Deactivate Recorder

Note: Appropriate forces will be determined by test prior to the experiment runs.

F. Environmental Requirements

All tests will be conducted in the Spacelab under comfort conditions usually obtained in any ground-based laboratory. Changes in thermal ambient can differentially affect muscle electrical activity, therefore, the thermal ambient must be maintained at a constant level ±3 °C. Noise will be maintained within the limits commensurate with habitability requirements. Because of the relatively low levels of muscle electricity (0.12 to 1.5 mV), the experiment must be protected from excessive electromagnetic interference (EMI).

G. Hardware Requirements

The experiment hardware consists of two systems:

1. EMG Measurement System:

   - EMG electrodes and associated harnesses.
   - Amplifiers and associated filter circuitry.

2. Skeletal Muscle Stress System

The EMG measurement system module is currently undergoing engineering testing in the Cardiovascular Laboratory of the Biomedical Research Division. The complete module measures approximately 10 cm x17.5 cm x30 cm (4 in. x7 in. x12 in.) and weighs approximately 1.35 kg (3 lb). Magnetic tape and strip chart recording are ancillary requirements.

The SMSA allows seated test subjects to exert known isometric-type forces with both upper and lower torso muscles. The apparatus incorporates a load measurement transducer which provides an output to the spacecraft data system and also drives a display viewable by the subject that is calibrated in pounds of force (newtons).

H. System Interface

The EMG equipment may be mounted on either a shelf in the Spacelab mockup racks or on appropriately fabricated mounting brackets. The SMSA can be stowed in the width of one single rack and will protrude only about 2.5 cm (1 in.) beyond the front of the rack, and will occupy approximately 125 cm (50 in.) of height. For experimental utilization, the chair must be removed from the rack, or moved forward until the front of the chair back clears the front of the rack.

The utilities required are as follows:

	Electrical Power		
Item	Maximum (W)	Voltage (V)	Frequency (Hz)
EMG System	400 mA	115	60
SMSA	100 mA	115	60

4.12 (continued)

I. Data Support Requirements

The EMG and force data will be collected and recorded into a magnetic tape system for later analysis on the ground. A spectral density analysis of the EMG will be utilized to provide muscle action potential amplitudes versus frequency of contraction data. The forces data will be used to determine the relationships between muscle tension output and changes in the EMG over the mission period of muscle disuse. Also the EMG/force/time relationship will be utilized to determine changes in the characteristics of muscle motor unit excitability and fatigability.

Data Support Measurements

PARAMETERS TO BE MEASURED		EMG	SMSA
EXPECTED VALUES OF PARAMETER	Units	mV/Hz	N (lbf)
	Average	0.8/50	3.6×10^4 (80)
	Range	0.2-1.5/5-400	1.1×10^4-4.5×10^4 (25-100)
MEASUREMENT CHARACTERISTICS	Frequency of Test	1/Crewman	1/Crewman
	Duration of Each Test	10-15 min	10-15 min
	Total Number of Tests in Mission	14	14

1. Preflight

   Take closeout photographs of experiment (stowed and unstowed).

2. In-flight

   - Measure Spacelab temperature when experiment is conducted.
   - Take 35 mm stills and 16 mm movie (or TV video) of at least two experiment runs.
   - Record real-time strip chart on ground during experiment runs.

3. Postflight

Return data - magnetic tapes of experiment data and any written logs.

J. FDF Requirements

The following items will be required:

- A timeline of daily activities.
- Detailed procedures and checklists.
- A maintenance and troubleshooting guide.

K. Preflight and Postflight Requirements

1. Preflight

Preflight measurements will include assembly of the experiment hardware, installation, checkout, and pretest runs. Other requirements are TBD.

2. Postflight

Postflight requirements will include data retrieval and analysis, removal of the hardware, and reporting. Subjects will be required to participate intermittently in the post-test protocol until pretest performance is essentially achieved.

L. Reporting

TBD in compliance with total mission requirements. Requirements can probably be met by a preliminary report at R+21 and a final report at R+60 days.

M. Training

Training will be initiated in the Engineering Division and completed in the DTU. Other training requirements for flight crew and support personnel are TBD. For planning purposes, crew training will initially consist of:

- Experiment familiarization - 2 hours.
- Procedures training - 3 hours.
- Baseline Data - 3 hours.

4.13 SMS II-13. SALIVARY ANALYSIS

Principal Investigator: W. J. Frome, D.D.S.

Project Engineer: C. R. Booher

A. Background

In the Skylab series of flights, analyses revealed frequent increases in IgA and lysozyme in the whole saliva. These collections were of whole saliva stimulated with chewing. The method of collection in this study is more sophisticated; with the use of a self-positioning collection device pure, uncontaminated parotid saliva can be obtained and flow rates can also be measured more accurately.

Ultimately, the objective is to measure selected parameters of parotid saliva and relate these findings to changes or potential changes in both oral health and general health.

B. Purpose

The purpose of this study in SMS-II is to develop a space experiment which will permit collection of pure parotid salivary fluid and measurement of the flow rate and levels of constituents in this fluid during space flight.

Secretory IgA possesses antibacterial and virus neutralizing properties and production appears to be stimulated by infection and antigen administration into mucous tissues. An increase in this component would be related to a stress which might be of microbial or viral origin.

Secretory lysozyme possesses antibacterial properties and probably is a protective factor in challenged oral environments. For this reason, and since the transfer of microorganisms in a space flight environment is of a high probability, it is appropriate to measure lysozyme levels in the parotid saliva of subjects.

C. Participants

1. Number of Crewmen

One or more crewmen, preferably two crewmen will be required. Each crewman will conduct the experiment on himself. Additional participation will increase the data base, but will not otherwise further development of the experiment.

2. Test Operations Team

The TOT will consist of the PI, PE, Test Control Team, Mission Crew, Test Operations Personnel (Science Manager and others), Data Specialists, and support personnel.

D. Functional Objectives

To determine through performance, possible iterations, and analyses:

- The suitability of experiment hardware with respect to selection, development, and operability, and to optimize hardware packaging.
- The crew training requirements.
- The crew procedures.
- The crew and experiment timelines.

E. Performance Requirements and Conditions

Equipment required will consist of the self-positioning collection device which will be furnished by the PI. It will be placed in the mouth by the subject and the parotid saliva will be collected in test tubes. It will be necessary to collect for five minutes, dispose of the collected sample, and collect for another 10 minutes. Method of timing should be that which will ensure accuracy of collection. The specimens will then be frozen for later analyses.

Subjects will hold pieces of sour candy in their mouths during the collection period, which may be of concern to those interested in dietary intake during the mission.

The experiment will be performed during pretest periods, twice during the mission, and postflight. Each test will occupy some 30 minutes per crewman for unstowing, sampling, cleanup, and restowing, including sample freezing.

F. Environmental Requirements

All tests will be conducted in the Spacelab under comfort conditions usually obtained in any ground-based laboratory. It would be advantageous to limit storage temperature to below 37 °C (100 °F), to minimize distortion of plastic. Samples will be stored in frozen condition.

G. Hardware Requirements

One complete assembly of the hardware for sampling will be furnished by the PI to each crewman subject. These hardware items are depicted in figure 4-6. Spacelab requirement is for stowage, cleanup, timing, logging, and sample preservation through freezing.

The experiment hardware consists of a round plastic disk to which a plastic wafer is attached. Two small metal tubes protrude from the plastic disk. The disk is 4 cm in diameter and the thickness with the plastic wafer is 2.5 cm. Two pieces of plastic tubing, each 24 cm in length are attached to the metal tubing. One is attached on the other end to a cut-off 12-gage needle inserted in a bulb syringe, and the other is inserted into a test tube. The bulb syringe is 7 cm long and 3.5 cm in diameter. The test tube is 10 cm long and 1.5 cm in diameter. An alligator clip is further provided (not illustrated) to attach the plastic tubing with the bulb syringe to the subject's clothing.

4.13 (continued)

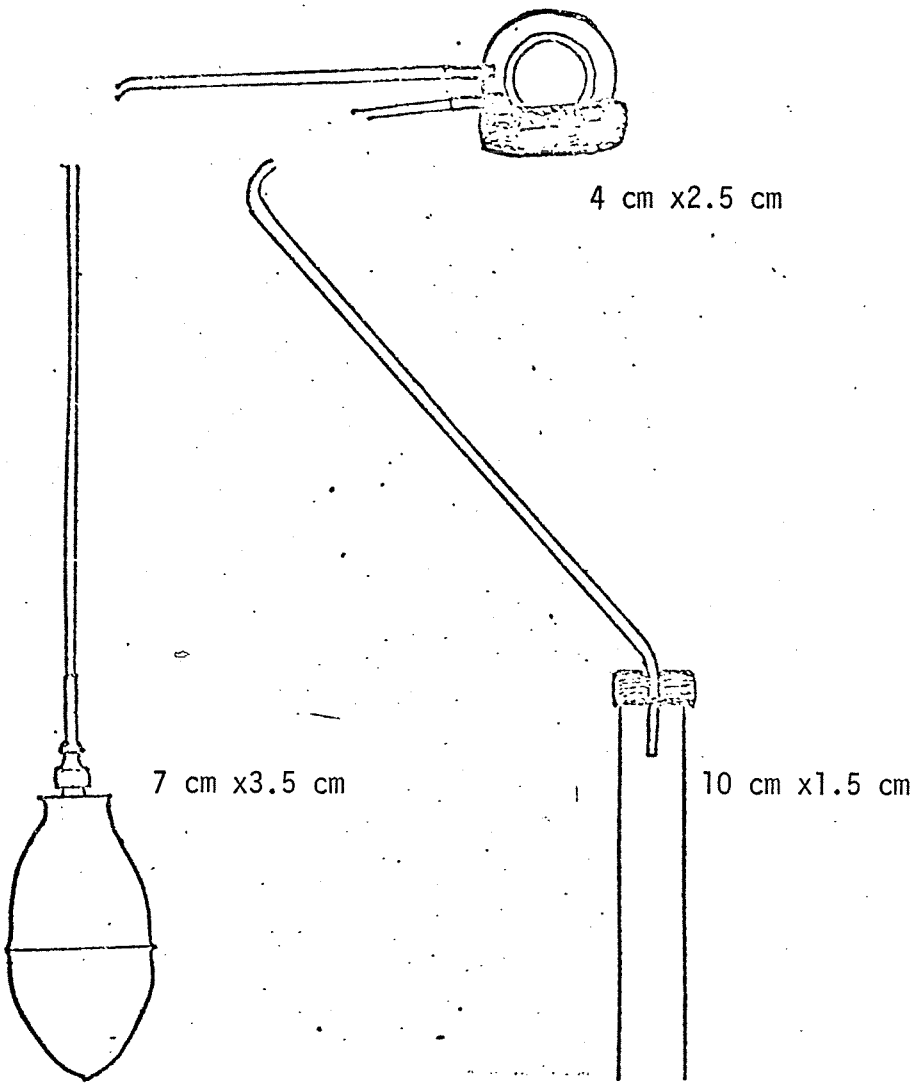


Figure 4-6.. Hardware Items Used to Sample Saliva.

For each subject, two additional 24 cm lengths of plastic tubing are provided for the second collection period during the mission.

While it is desirable to wash the equipment in water after each use, air drying would be satisfactory.

4.13 (concluded)

H. System Interface

Interfaces with Spacelab will be in stowage, environmental control, ability to time collections, and ability to make a log of activity. Water-wash of equipment will be desirable. One drawer of stowage will be required.

I. Data Support Requirements

Data will consist of sampling times and a log of activity.

J. FDF Requirements

A timeline of daily activities and detailed procedures will be required.

K. Preflight and Postflight Requirements

1. Preflight

Preflight requirements will include assembly of the experiment hardware, installation, and pretest runs. Training will be initiated in the JSC Dental Laboratory and completed in the DTU. Other requirements are TBD.

2. Postflight

Postflight requirements will include data retrieval and analyses, removal of frozen specimens, removal of the hardware and reporting. Analyses of specimens will be conducted in a back-up laboratory, to be arranged.

L. Reporting

TBD in compliance with total mission requirements. Requirements can probably be met by a preliminary report at R+21 and a final report at R+60 days.

M. Training

Crewmen must be fitted with device and instructed in its use. Total time will be less than one hour each.

4.14 SMS II-14. THE EFFECT OF ZERO GRAVITY ON MUSCLE-LIKE CONTRACTILE PROTEINS

Principal Investigator: H. R. Henney, Jr., Ph. D.
Co-Principal Investigator: R. C. Graves
Project Engineer: J. Lintott

A. Background

It has been shown that cytoplasmic streaming in the myxomycetes is due to the calcium cation (CA^{++}) dependent contractile actomyosin complex similar to that found in the muscle of man, and general slowdown of protoplasmic streaming has been shown to occur at low magnetic fields.

Muscle weakness in man during prolonged space flight could be due to some effect of zero-g and/or low magnetic fields on the contractile proteins. Since the actin-linked actomyosin regulation of *Physarum* sp. is analogous to the Ca^{++} sensitive control proteins found in the muscles of higher animals, any adverse effect found in this system could help clarify this problem in man.

B. Purpose

The purpose of this study in SMS-II is to develop a space experiment which will determine the response of the rhythmic reversible streaming of the myxomycetes to zero-g and low magnetic fields by determining if there is any visible effect of space flight on the muscle-like contractile proteins of *Physarum* sp.

C. Participants

1. Number of Crewmen

   One person will be needed as an observer.

2. Test Operations Team

The TOT will be made up of the PI, PE, Test Control Team, Mission Control Team, Mission Crew, Test Operations Personnel (Science Manager and others), Data Specialists, and support personnel.

D. Functional Objectives

To determine through performance, possible iterations, and analyses:

- The suitability of experiment hardware with respect to selection, development, and operability, and to optimize hardware packaging.
- The display and recording requirements external to the experiment.
- The crew training requirements.
- The crew procedures.
- The crew and experiment timelines.

E. Performance Requirements and Conditions

A Petri dish containing a plasmodium will be placed under the microscope and observed for 10 minutes three times a day, and the number of reversals and time of each will be recorded.

F. Environmental Requirements

All tests will be conducted in the Spacelab under the comfort conditions usually obtained in any ground-based laboratory. The specimens will be maintained in an incubated Petri dish at all times except when they are being viewed. Inadvertent exposure to high or low temperatures may result in death of the organisms.

G. Hardware Requirements

Hardware will consist of a shaker, TV microscope, incubator, and workplace. A time reference is necessary. Shaker design will be furnished by the PI.

H. System Interface

System will require power for the incubator, the microscope lamp, and the TV camera. The TV images should be transmitted to the exterior of the DTU, simulating downlink. Part of one drawer from one rack will be used for log sheets and supplies.

I. Data Support Requirements

Videotaping and downlink capability for taped images will be required.

J. FDF Requirements

A timeline of daily activities and procedures and checklists will be required.

K. Preflight and Postflight Requirements

1. Preflight

Preflight requirements will include assembly of the experiment hardware, installation, checkout, and pretest runs. Training will be initiated in the JSC Microbiological Laboratory and completed in the DTU. Other requirements are TBD.

2. Postflight

Postflight requirements will include tape retrieval, removal of hardware, and reporting. Preflight, in-flight and closeout photographs of the experiment in place will be required.

4.14 (concluded)

L. Reporting

TBD in compliance with total mission requirements. Requirements can probably be met by a preliminary report at R+21 and a final report at R+60 days.

M. Training

Training requirements for flight crew and support personnel are TBD.

Sections 4.15 through 4.20

The above captioned section numbers are reserved for the alternate experiments for the SMS-II. Detailed information for these experiments has not been required. General information for these experiments will be found in the *Life Sciences Spacelab Simulation II, Development Plan,* DE SMS-II-017.

4.21 SMS II-21. COSMIC RAY MAGNETIC SPECTROMETER

Principal Investigator: R. L. Golden, Ph. D.
Project Engineer: W. G. Davis

A. Background

The discovery in 1912 of cosmic rays and their great penetrating power opened a scientific field that has contributed much to our knowledge of the universe. The energies available with cosmic ray particles greatly exceed those produced by the largest particle accelerators.

At JSC, balloon-borne payloads have been flown several times yearly for the last several years. These flights at 36 000 meter (118 000-foot) altitude usually have durations of up to 20 hours. This experiment is considered to be a prototype development for a Space Shuttle payload.

High energy astrophysics is an important and critical part of the present exciting and explosive growth of our knowledge of the cosmos. It is conducted of necessity from space, because the Earth's atmosphere absorbs the cosmic rays, electrons, and positrons to be observed.

The Life Sciences Directorate will conduct medically oriented experiments in a Spacelab module and the Science and Applications Directorate (S&AD) will conduct a Cosmic Ray Physics Experiment (Cosmic Ray Laboratory (CRL)) on a simulated Spacelab pallet. The Spacelab pallet experiment will be controlled from the aft flight deck Payloads Specialist Station (PSS).

This experiment plan augments the information presented in the SMS-II Development Plan (DE-SMS-II-017). The CRL objectives and implementation requirements for SMS-II are described in this document.

B. Purpose

The purpose of this document is to define the following aspects of the SMS-II CRL experiment:

- Objectives
- Pallet hardware
- Controls and displays
- Data system
- Support requirements
- Operations

C. Participants

1. Number of Crewmen

One crewman experienced in high energy physics and spectroscopy will be required for eight hours each day to perform superconducting magnet charging, experiment check-out, calibrations, setting of sensitivities and thresholds, data acquisition and preliminary interpretation, experiment reconfiguration, experiment shutdown, and magnet decharging. Other crewmen will be needed for five minutes of monitoring every two hours during the time that the primary crewman is off duty.
will be needed for five minutes of monitoring every two hours during the time that the primary crewman is off duty. AOS/LOS functions will be provided by the SIM-SUP by means of an auxillary command encoder.

2. Test Operations Team

A payloads officer will interface the operations of the science monitoring area, and the remote science support area in building 265, to the Mission Control Center.

The TOT will be made up of the PI, PE, Test Control Team, Mission Control Team, Mission Crew, Test Operations Personnel (Science Manager and others), Data Specialists and support personnel.

D. S&AD SMS-II Objectives

SMS-II will provide an opportunity for S&AD scientists, engineers, and science management personnel to gain experience with requirements and constraints for implementing and operating complex multidiscipline Shuttle payloads. The S&AD SMS-II objectives include the following.

1. Engineering and Payload Operations Objectives

- To evaluate pallet operations for large scientific experiment packages.
- To evaluate Shuttle utility operations and payload access constraints for pallet operations.
- To evaluate the PSS for accommodating controls and displays and a standard digital data interface.
- To evaluate operations involving experiment control from the aft flight deck.
- To evaluate spacecraft operations constraints as they affect experiment operations.
- To develop and evaluate a method of experiment arrangement.
- To evaluate the use of Computer Automated Monitor and Acquisition Control (CAMAC) data systems in payload operations from the aft flight deck.
- To evaluate plans for training crews who have been selected from various disciplines to operate multidiscipline payloads.
- To evaluate use of air-to-ground (A/G) communications in support of multidiscipline payload operation activities.
- To evaluate Shuttle orientation as it affects operations of cosmic ray experiments.
- To evaluate onboard flight planning by the crew as it affects multidiscipline payloads.
- To collect baseline data to generate improved payload operations management concepts.

- To evaluate a remote area science monitoring concept.
- To evaluate a Polaroid hard copy concept.
- To evaluate a concept of near real-time payload data evaluation, reduction, and analysis.

2. Scientific and Experiment Related Objectives

The payload to be used in this simulation is a balloon-borne cosmic ray laboratory. It has been flown twice to altitudes of 35 000 meters (118 000 feet) to measure cosmic rays at the top of the atmosphere. The experiment consists of 3 tesla (T) (30 000 gauss) superconducting magnet that deflects charged particles and measures their momentum.

Scientific objectives for the measurements made in SMS-II are as follows:

- To determine accurately the muon energy spectra and charge ratio.
- To determine accurately the energy spectra of gound level electrons.

E. Performance Requirements and Conditions

Figure 4-7 shows the proposed timelines and functions of CRL personnel for SMS-II.

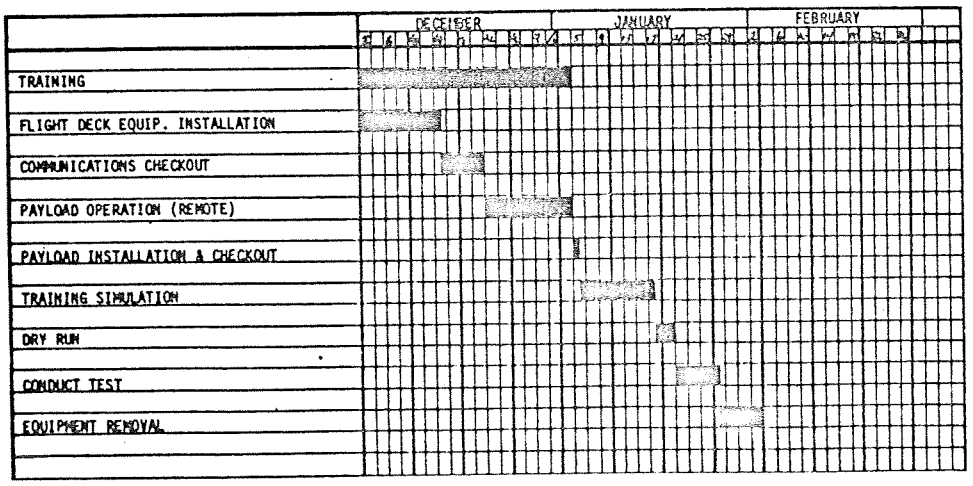


Figure 4-7. S&AD CRL Activities Schedule.

The payload will not be moved until January 1. The payload will be operational and checked out remotely from the flight deck by telemetry. A receiver and antenna will be temporarily installed for the checkout. Prior to SMS-II, command and routine operation of the payload will be accomplished by operation from building 265. It will be necessary for CRL personnel to perform payload modifications and functional checks between January 1 and the beginning of SMS-II. Due to balloon flight schedule requirements, use of the payload in the simulation cannot continue past February 1, 1976, since payload balloon operations will be required in April. All modifications and functional checks will be scheduled on a noninterference basis with SMS-II activities.

1. Experiment Preparation

   The superconducting magnet will be charged before launch. Experiment activation will occur as soon as possible after orbit is achieved.

2. Experiment Operations

   Flight control will consist of standard Shuttle operating procedure: during orbit phase, the PS will perform experiment setup, design, configuration, and data reduction for eight hours each day. In addition, throughout the remainder of the day (16 hours) five minutes of monitoring at two-hour intervals will be required by one of the three crewmen.

3. Post-test Tasks

   Reentry preparations will require the PS to perform four continuous hours of experiment deactivation; one to discharge the superconducting magnet and three hours to accumulate data with the superconducting magnet off.

4. Maintenance and Calibration

   Maintenance will be performed only in the event of a failure. Calibration will be accomplished by the payload specialist, as required.

F. Environmental Requirements

- Experiment control is located on the Orbiter aft flight deck. Normal shirtsleeve Orbiter environment is satisfactory. Lights should be capable of regulation in order to view display scopes. Experiment equipment is located on a pallet simulator. Temperatures should be held below 49 °C (120 °F) for proper equipment operation.
- It is known that some radio frequency interference (RFI) problems currently exist with the electronic equipment, but it is not believed that the level is such to currently interfere with other experiments.

G. Hardware Requirements

Experiment Design

The experiment concept employs the use of a superconducting magnet. Particle detector systems are used to identify each particle as it traverses the system. The detector systems are housed on a pallet in a pressurized module, and the experiment in the pressurized module is controlled by NIM-CAMAC equipment (Internationally standardized electronics: Nuclear Instrument Modules-Computer Automated Modular Acquisition and Control equipment). Electronics in the payload are controlled by NIM-CAMAC command on the aft flight deck.

Equipment Description

The experiment hardware operates many detectors in unison to determine mass energy and charge of the nuclear particles. The basic piece of hardware is a liquid helium cooled superconducting magnet. Several types of radiation detectors are used to determine the deflection of particles by the magnetic field of the superconducting magnet. Gas Cerekov detectors are used at the top of the system.

Scintillation detectors are used above and below a stack of multiwire proportional counters (MWPC) so that coincidence between the two sets will trigger the collection of data from the MWPC stack. This will determine the curvature of the particle as it travels through the magnetic field and hence determine the momentum of the particles.

Below this stack is another stack of alternating scintillation counters and lead absorbers. The interaction of the particles will be assessed in this stack. In addition to monitoring the data stream, there are 100 engineering parameters to be monitored during the operation of this experiment. This experiment was flown successfully in a pressurized module on several balloon flights at altitudes of approximately 36 000 meters (118 000 feet).

Figure 4-8 is a functional diagram showing the payload, control, data, and ground station systems for the SMS-II CRL experiment.

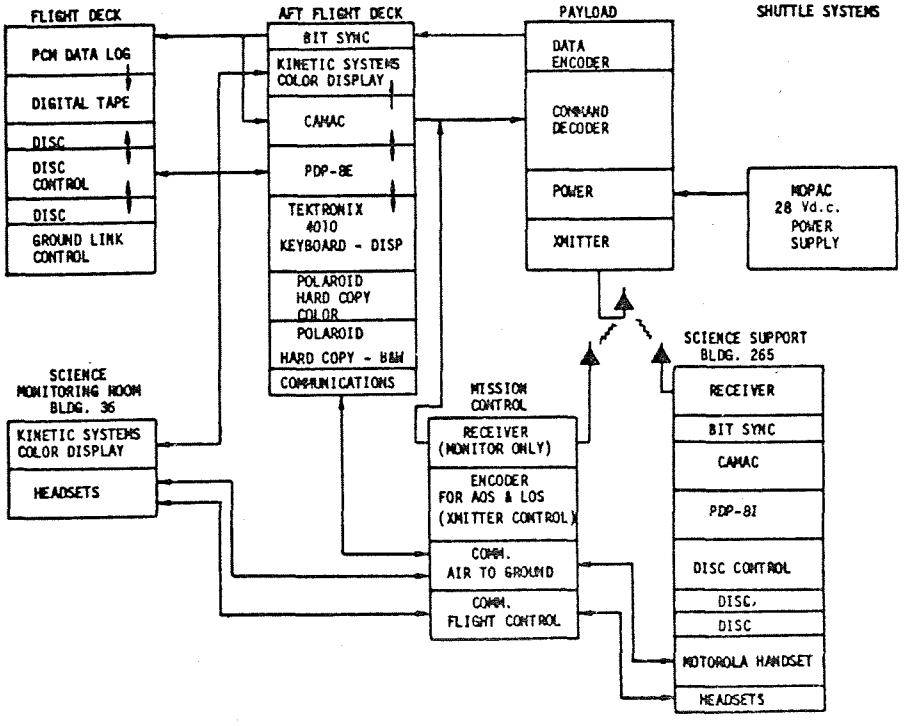


Figure 4-8. SMS-II CRL Functional Systems.

This hardware is considered to be an operational prototype of a Space Shuttle payload. The gondola of the S&AD balloon-borne Cosmic Ray Laboratory will be simulating the Spacelab pallet-mounted experiment. The Shuttle computer and aft flight deck controls and displays will be simulated using balloon flight control equipment.

Assembly sketches are available in the CRL-2 *Operations Handbook* in Science and Applications Directorate Physics Branch for the prototype system.

The following three sections describe the hardware to be provided.

1. GONDOLA (Simulated 3-Meter Pallet)

All payload systems are internal except for power. The core of the experiment consists of a superconducting magnet, with a 3 T (30 000 gauss) field, and a stack of eight MWPC chambers which accurately locate the cosmic rays as they penetrate the stack. The location of the particle can be resolved to 0.2 mm in each chamber and the effect of the magnet on bending the particles can be used to resolve the momentum of the particle.

A gas Cerenkov counter and two scintillating plastic detectors are above the chambers. Two of these are used as triggers for particle events.

Below the chambers is a stack of seven shower counters (scintillating plastic) with lead absorbers between them. The mass of the particle can be determined from this stack. Thus, the particle momentum can be resolved into mass and charge. Two detectors in this stack are used as triggers.

An event is sensed by the four trigger detectors in the assembly and the data are coded in a pulse code modulation (PCM) word format.

4.21 (continued)

H. System Interface

The payload portion is a balloon gondola which, for the purpose of this test, will be sitting on the floor behind the Spacelab mockup. The area required is 3 m x3 m (10 ft x10 ft.).

Mounting requirements for the controls and displays are in 19-inch racks in the Payloads Specialist Station on the aft flight deck of the Orbiter.

Payload power requirements: The gondola operates on 28 Vd.c. power. Ag-Zn batteries are used during a balloon flight. Ground power is provided by a Trygon power supply unit that will be used for power in SMS-II.

The amperage required at 28 Vd.c. is 28 A nominal with peak usage of 36 A possible being used for only 1 to 2 hours. After power up of the payload on-orbit, it is desired to keep continuous power on the payload until experiment deactivation.

The rollaround power unit with the Trygon power supply for SMS-II will be located in the experiment area by the side door in the high bay. Power will be run from the flight deck with a breaker control on the flight deck. The amperage usage will be about 30 A at 110 Va.c. due to the inefficiency of the power supply, and it will be unmonitored. Flight power consumption will be taken from the 28 Vd.c. usage as monitored at the payload specialist station, since the power in the Shuttle era will be provided by the 28 Va.c. supply from fuel cells.

Nominal power of 28 A will be needed from launch plus 3 hours to 5 hours before retroburn. Power will also be required from launch minus 6 hours to launch minus 5 minutes to support payload systems checkout.

4.21 (continued)

2. AFT FLIGHT DECK

The equipment on the aft flight deck is the same as that which is used as a ground control station for balloon operations. The displays and controls are functionally equivalent to the desired functions at the payload specialist station. The heart of the system is the CAMAC equipment. This equipment is an international standard for modular digital electronics. CAMAC modules are commercially available for various digital electronic functions and analog-to-digital interfacing.

H'. System Interface

CAMAC crates interface into computer systems and provides standard interface for digital data that can be adapted for most functions.

The computer system for control, for the purposes of the simulation, will be a PDP-8E. The function of this computer on an actual Shuttle mission will be to interface with Shuttle computer designated for on-orbit experiment operations. The orbiter computer and its functions of data handling, mass storage, and downlink will be simulated by two disc units during SMS-II.

Figure 4.9 shows the physical layout in the payload specialist station.

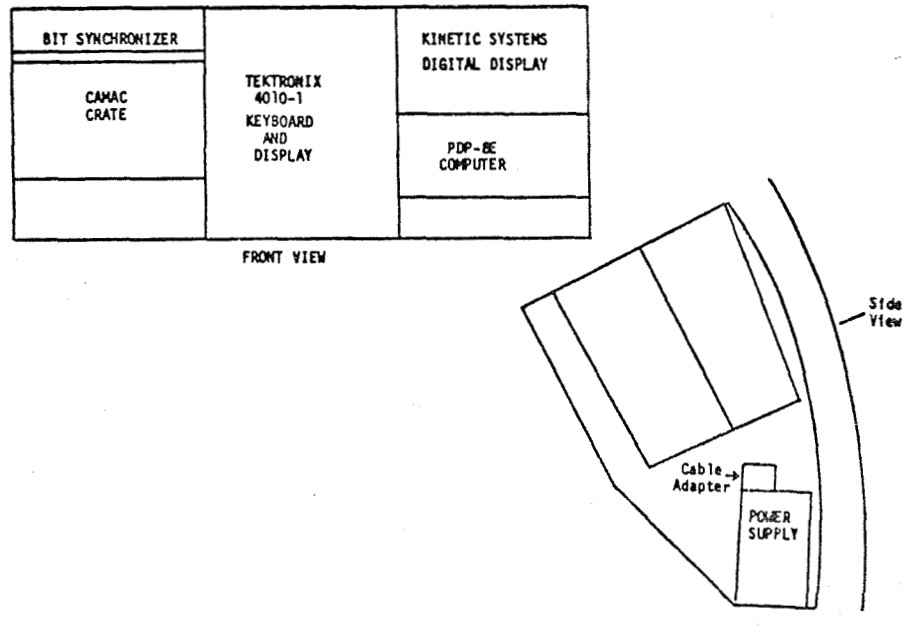


Figure 4-9. Physical Layout of Aft Flight Deck Payload Specialist Station.

4.21 (continued)

- Bit synchronizer - The data from the payload are generated in PCM format for transmission to ground stations. The bit sync picks up the two lead words in order to feed a clock pulse to decoding equipment. The output is in the form of a clock pulse and a non-return zero (NRZ) code data stream. This unit is used to drive the digital tape unit and feed NRZ data to the CAMAC unit.
- CAMAC crate - A CAMAC controller interfaces this internationally standardardized digital data system to the PDP-8E computer system (can be interfaced to most laboratory computers). The modules for this experiment are listed below.
  - Kinetic Systems Color Digital Display Controls (Pos 1-4) - These four modules provide color drive, character generation, and other functions for the color digital display. This display unit acts as a storage scope and updates various values as commanded. All display of information and color selection is directed by software in the PDP-8E.
  - Real-time clock (Pos 5 and 6) - This clock feeds days, hours, minutes, seconds, and one-tenth seconds to the CAMAC crate and can interrupt or be interrogated by the computer in order to provide time code generation for the experiments. This time is displayed on the color digital display and is used to tag all engineering data.
  - NRZ - Parallel Input Module (Pos 6 and 7) - This module decodes and stores up to sixty-four 12-bit words of data from the data stream and outputs them to the PDP-8E for processing. Both engineering and scientific data are input through this module. This module may decode NRZ code data or parallel data or recieved data or software from a modulator/demodulator (MODEM).
  - Real-time clock (Pos 16 and 17) - This real-time clock is not used by the software presently. This will be used as an elapsed timer on the aft flight deck. It will also be used as a spare for the system clock in positions 5 and 6

- Dual output register (Pos 18) - This module acts as a command driver for the command encoder. Commands issued from the keyboard through the PDP-8E are output in a format suitable for the command encoder.
- Command encoder (Pos 19-22) - This is a NIM standard module which has been interfaced to CAMAC for power only. It is driven by the dual output register, and commands will be hardlined to the payload. Usually, this unit drives a transmitter for telemetry of commands.
- Dataway display (Pos 23) - This device displays all signal activity on the 86-line data bus that is the heart of the CAMAC system. An operator can get a qualitative feel for the data rates and activities of the CAMAC crate by observing this display.
- Vacant positions (Pos 8-15) - These positions could use any of the several hundred modules available from 50 different manufacturers to perform different functions. These positions for the simultion will carry spare modules. These will be mounted on standoffs so they will not consume power until they are used.

° Kinetic Systems Color Digital Display

- This unit will display digital information in a color format. The color codes available are white, green, light blue, dark blue, yellow, red, and pink. During the simulation, scientific and engineering information will be displayed.
- The science TV (STV) display will present experiment information and the actual values of the 37 data words that describe the passage of one particle through the payload. Although much higher data rates can be handled by the computer, the display scan for

events is about two/second. The STV display is used to insure that the data stream electronics is operating properly and that the 32 digitizers are operating.

- Engineering TV (ETV) will be the usual mode of display during the simulation. Information displayed is experiment identification, date, G.m.t. time, scalers of the various coincidence modes, and 100 engineering values for the following parameters: calibration, low-voltage power supplies, temperatures, discriminator levels, logic levels, trigger modes, magnetic field, gas pressures, liquid helium levels, high-voltage levels, and rates of the various detectors. These values are color coded in the following manner:
  - Green - nominal
  - Light Blue - noncritical low
  - Yellow - noncritical high
  - Flashing Light Blue - semicritical low
  - Flashing Yellow - semicritical high
  - Flashing Red - critical high or low
- If the switch register on the PDP-8E is set to 0000, then the following sequence will be activated if an engineering value reaches the critical stage.
  - The engineering display is frozen,
  - Commands are automatically sent to shut down all high voltages on the payload,
  - A beeper on the keyboard is activated, and
  - A red "SHUTDOWN" is printed by the critical value on display

° PDP-8E computer - This unit is the programable handler for the controls and displays, and is the means by which data are routed to the discs simulating the Shuttle AP-101 computer. Programs are stored on the disc units and overlayed

in the computer memory. Operations on the computer console will be limited to bootstrapping the disc for starting programs and for running diagnostics (if required).

- Tektronix 4010-1 - This keyboard and display unit will be used for all control of the experiment. All commands for payload control will be issued by the keyboard. All configurations for display are keyboard controlled. The display screen of this unit will be used for graphics in the pulse height spectra mode to insure adequate operation of all detectors.
- Tektronix 4010-1 power supply - This unit is the power unit for the scope and keyboard described above and will sit below the rack-mounted equipment on the floor below the racks of the payload specialist station.
- Hard copy cameras - Two Polaroid® cameras will be used for hard copy. One will use color film for the Kinetic Systems scope and one will use B&W film for the graphics on the Tektronix scope display. These will be stowed during launch and reentry.
- PSS power requirements: all values are at 115 Va.c.

Equipment	Nominal (A)	Peak (A)
Bit Sync	0.3	0.3
CAMAC	2.7	3.0
Kinetic Systems Scope	1.1	1.1
PDP-8E Computer	3.5	3.5
Tektronix 4010-1 and Supply	1.4	1.4
TOTAL	9.0	9.3

All above equipment will be turned on at L+3 hours and off at R-5 hours. Power will be required from L-6 hours to L-5 minutes to insure that all systems are operable.

3. FLIGHT DECK

During Shuttle on-orbit operations, it has been suggested that one of the AP-101 computers be used for payload operations. AP-101 will use the Houston Assembly Language (HAL) programing language.

For purposes of SMS-II, we will simulate the AP-101 computer for only the functions of mass storage, retrieval of data and programs, and routing of data to digital tape recorders. Control and display programing will be on the PDP-8E because it uses a language that is familiar to the CRL experimenter.

H". Systems Interface

The equipment that will be located in front of the aft flight deck and will simulate the AP-101 operations is as follows:

- PCM decoder - Takes data and clock from the bit sync and drives the PCM memory.
- PCM memory - Stores 32 events of thirty-seven 12-bit words and drives the digital tape unit.
- Digital tape unit - Records data records of 32 events, each taken from PCM memory unit. During SMS-II, ground level muon and electron data will be recorded. This tape will need to be changed by outside CRL personnel once per day.
- Disc controller - Acts as mass storage controller to drive disc units.
- Two disc units - Mass storage devices simulating AP-101 computer.
- Power requirements: Power requirements for the devices on the flight deck will be Shuttle chargeable and will not be charged to the payload.

For purpose of the wiring for the SMS-II simulator, six outlets at 115 Va.c. are needed with a total current requirement of 9.0 A.

4.21 (continued)

I. Data Support Requirements

1. GONDOLA

° Preflight

None

° In-flight

- Data output

Data will go from the gondola to the aft flight deck by one 50-ohm cable.

Data will also be transmitted to building 265 by a transmitter operating on 1491.5 MHz. A color digital display, parallel to the one on the aft flight deck, will be located in the building 36, Science Monitoring Room. Output of the transmitter signal will be monitored in Mission Control by a receiver.

Data will be decoded on the aft flight deck and clock pulses set up by a bit-sync. These data will be fed to the CAMAC digital data interface for display and data handling.

Real data on ground-level muons and electrons will be taken during SMS-II and used for scientific interpretation. The data and clock from the bit-sync will be input to a digital tape unit that will simulate the AP-101 flight computer for mass storage.

- Control input

A command encoder on the aft flight deck will be used to control high voltages, logic, discriminator levels, magnet control, and other functions of the payload. One 50-ohm cable between the aft flight deck and the payload is required for this function.

4.21 (continued)

An additional encoder will be placed at the simulation controller station. By using command 00 the transmitter will be turned on to simulate acquisition of signal (AOS) of the data to be transmitted to building 265. Loss of signal (LOS) will be simulated with command 01.

- Postflight

  None

2. AFT FLIGHT DECK

- PSS Control and Data Lines
  - Data input - Data will come from the payload by one 50-ohm cable and go to the bit sync.
  - Data output - Data will be monitored at the payload specialist station. Mass storage of data will be routed to the disc units simulating the AP-101 storage by one data bus ribbon line. Due to connector difficulties, another ribbon will be used in the simulation to connect the disc controller to the CAMAC crate, since this is the only easily accessible PDP-8E Omnibus connector. This is a deviation from the functional block diagram, figure 4-8.

    Two 50-ohm lines will go from the bit sync to a digital tape unit on the flight deck. This will be used to record real data on ground level muons and electrons during SMS-II. Information recorded on these digital tapes will not be fed back into the simulation.

    Figure 4-10 shows the cable interconnections of the fore and aft flight decks.

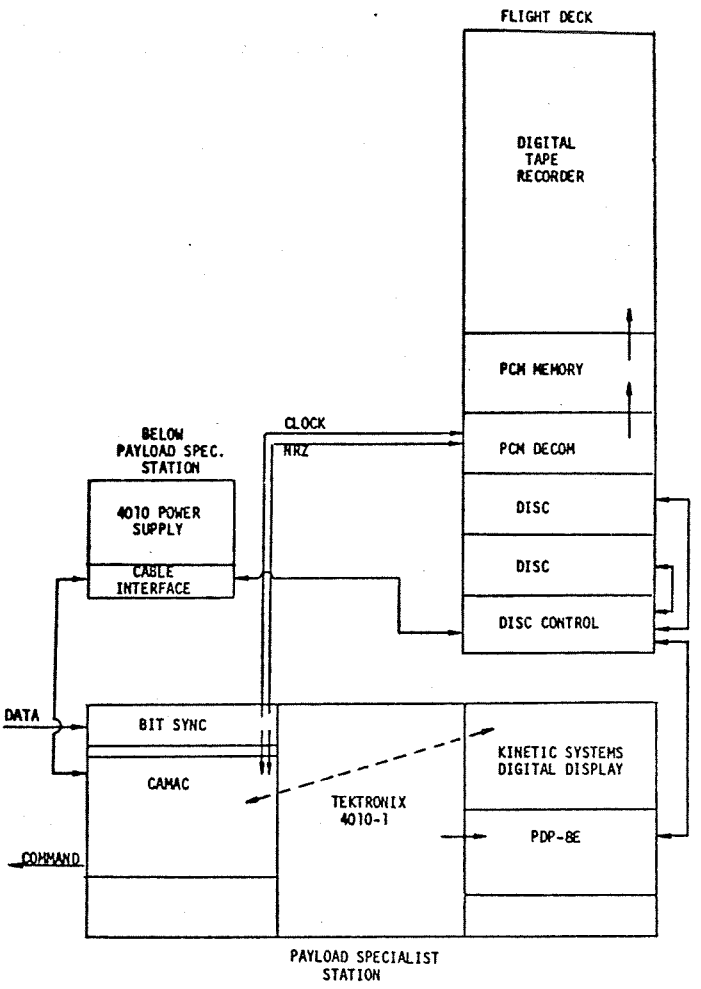


Figure 4-10. Electronics Flow Fore and Aft Flight Deck.

° Control output - The command encoder at the payload specialist station will control functions of the payload by 100 different commands. One 50-ohm cable between the aft flight deck and the payload is required.

3. FLIGHT DECK

Control and Data Lines

Figure 4-10 shows the cable interconnections on the flight deck and the interconnections to the payload specialist station.

4.21 (continued)

J. Flight Data File Requirements

A timeline of daily experiment activities will be required. General tasks to be performed at various times and checklists including maintenance and troubleshooting guidelines are detailed as follows:

1. General Tasks

° Preflight Operations

• Day L-1 (4 hours)
1300-1700 hours G.m.t. (0700-1100 hours c.s.t.) PS-2 on flight deck. (Backup or designee may be used.) CRL personnel will fill consumables. Complete payload checkout performed. Complete ground station checkout performed.

NOTE

Because of rest cycle conditioning, PS-2 must be relieved no later than 1700 hours G.m.t.

• Hour L-6
PS-2 (or backup) on flight deck. Magnet charged. Consumables topped off. Final QA check. Gas valving configured. Engineering and science checks.

• Hour L-4
Payload bay closeout.

• Hour L-1
PS-2 on flight deck. Engineering and science checks.

° Experiment Activation

• Hour L+3 (approximately 1 hour)
• Unstow and set up cameras (5 min)
• Visually check PSS hardware (5 min)
• Power to PSS (5 min)
• Power to payload (5 min)
• High voltage to payload (10 min)
• Science check and setup (30 min). (Desire AOS and comm for science check.)

° On-Orbit Operations

General experiment operations will require a minimum of 8 hours per day of PS-2 time. This time is for normal operations and does not include time possibly needed for experiment malfunctions and workarounds. It is desired that the last hour of the PS-2 work period be reserved for payload evaluation and operations planning by the PS-2 and the building 265 science support personnel. This activity requires that the spacecraft be AOS (*i.e.*, data are being transmitted to building 265), and requires voice communication between PS-2 and building 265 support personnel. This will not be a requirement for day 1, since experiment configuration for first day will have been planned preflight.

Functions to be performed during the experiment operating period are:

- Experiment operation, engineering monitoring,
- Real-time data analysis and evaluation,
- Real-time reconfiguration based upon data analysis,
- Discussions with science support regarding experiment setup, operation, and reconfiguration,
- Real-time failure analysis and workarounds, and
- Aft flight deck system evaluation and failure repair.

° Experiment Monitoring

- PS-2

  Other than the 8 hours mentioned previously, the PS-2 will monitor the experiment at least every 2 hours when he is awake. Monitoring functions will be deeper than those performed by the other crew members as science evaluation as well as engineering evaluation will be made. Fifteen minutes per monitoring activity should be adequate time.

Off time may be used by flight planning to integrate the PS-2 into medical experiments for which the PS-2 is qualified or where the PS-2 is suitable as a subject, bearing in mind the scheduling of the routine monitoring function.

- MS and/or PS-1
  This monitoring function could be also accomplished by the CDR or PLT if they are in the simulation.

The time period for the monitoring procedures is every 2 hours with about 5 minutes required for each monitoring function. The shortness of the time period required is due to the presence of the PS-2 who can set up monitoring functions such that parameters that need close watching are set up with alarms and color coding on the screen.

NOTE

In Shuttle era, we anticipate this can also be done by ground-to-air telemetry.

The timeline for this monitoring is flexible as long as the guideline of one period of two hours is followed in principle.

- Abnormal Operations
  - South Atlantic Anomaly (SAA)
    The SAA is a region where the magnetic field of the Earth traps protons and electrons at altitudes low enough to intersect the trajectories of Earth orbiting spacecraft.

    The CRL has detectors that can be damaged by high particle fluxes such as those that could occur in passing through the SAA. These detectors must be

shut off during SAA passes, and it must be verified that these detectors are shut down. The time and delta time of the SAA will be forecast by Mission Planning and Analysis Division (MPAD) and a member of the crew will issue the command, "TURN PAY OFF," prior to entry in the SAA. After passing through the SAA, the crewman will command, "TURN PAY ON." This will require about 5 minutes. The "TURN PAY OFF" command will activate software that simulates a shut down payload on the output data displays. However, the payload will actually continue to operate. It is desirable that the monitoring function be flight scheduled at the times of the passes through the SAA.

Description of the SAA is contained in a memo from DF3 to FM2, dated 1 May 74 (74-FD37-94). For purposes of SMS-II, the coordinates of that portion of the SAA that will affect this experiment are as follows:

-20° to -30° latitude
-30° to -40° longitude

With these constraints, the maximum time in the SAA is about 3 minutes.

- Emergency shutdown
  By setting the PDP-8E switch register to 0000, a software sentry will be armed. If a critical engineering parameter becomes considerably out of normal, a software shutdown of the payload high voltages will be ordered. Parameter tolerances may be changed by software command by PS-2. Normal parameters monitored in this mode are current,

chamber gas pressures, magnet discharge, and multiwire proportional counter rates. Others may be added or deleted in real time during the test.

If an emergency shutdown occurs, the PS-2 should evaluate the problem. Evaluation may also be done by MS or PS-1 in conference with the remote science support area.

° Experiment Deactivation (minimum 4 hours)
Two major phases of this operation are required. The first portion is to execute a magnet discharge which takes approximately 1 hour. Accumulation of about 3 hours of data are obtained for calibration purposes after the magnetic field has gone to baseline.

The high voltages are then turned off and verified and power to the flight deck and payload are terminated. Equipment used in the conduct of the CRL experiment is then stowed for retroburn.

° Ground Operations
Following are guidelines for ground support of the operation of the SMS-II CRL experiment.

- Flight control
  Shuttle SOP
- Simulation Supervisor
  Several functions exist that can be used by the SIM-SUP for the CRL payload.

A short 19-inch rack, including command encoding equipment, will be provided for the use of the SIM-SUP. Figure 4-11 shows a layout of this equipment. Command 00 may be used to turn the transmitter to ON and command 01 to turn the transmitter to OFF, to simulate

AOS and LOS. Building 265 will receive this transmitted signal and the SIM-SUP will monitor the signal AOS and LOS by a receiver. A switch will also be provided on this rack to disconnect the engineering display in the science support room to simulate LOS. The CRL payload could be controlled by way of the SIM-SUP command encoder. However, this should only be done in a contingency situation, and should never be done unless performed under the direction of the PS-2, PE, or PI.

Although the possibility is remote, an accident such as a magnetic object getting close to the payload would require immediate shut down of the magnet. This can be done by commands via the encoder.

Passing through the South Atlantic Anomaly will be handled by flight planning of crew activities (See Abnornal Operations, SAA.)

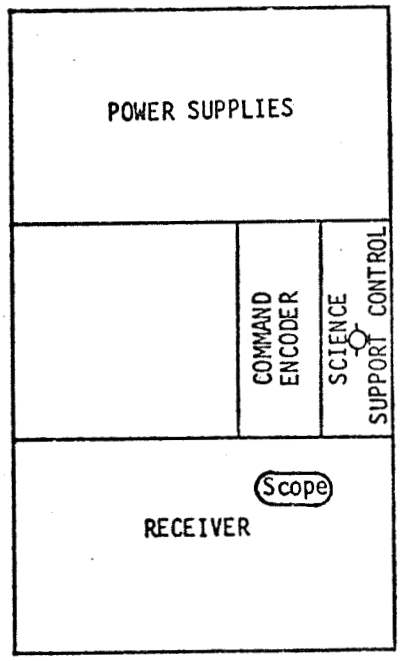


Figure 4-11. SIM-SUP CRL Equipment Layout.

4.21 (continued)

- Payload Officer
  - As previously indicated, the payload officer will interface the operations of the science monitoring area, and the remote science support area in building 265, to the Mission Control Center.
  - Scheduled activities of communications between the aft flight deck and building 265 will be implemented, along with securing air-to-ground communications upon request.
- Science Monitoring Room (SMR)
  S&AD personnel will provide 24-hour support of the CRL in the SMR. Status of critical payload parameters will be monitored continuously via a digital color display like the one at the PSS. S&AD SMR personnel will maintain a log of all SMS-II activities related to the CRL experiment, and will provide inputs for the daily status reports.
- Remote CRL Payload Support Center
  The remote payload support center in JSC building 265 will be operated during SMS-II. Figure 4-12 shows the equipment that will be used in building 265. All equipment, except for the Kinetic Systems digital color display system that is at the payload specialist station on the flight deck, is duplicated and several display systems and an analog tape unit are added.

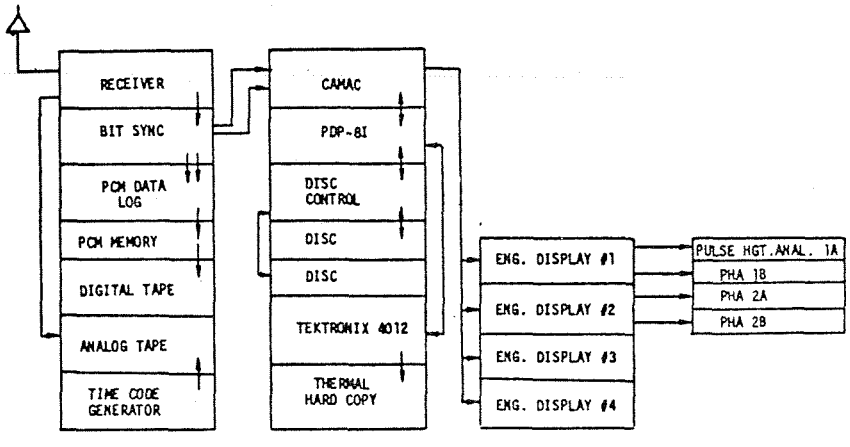


Figure 4.12. Remote CRL Payload Support Center, Building 265.

The remote payload support system will provide ground recording of the data that are transmitted during AOS and will provide the capability for ground analysis of CRL scientific data. Normal operation will be 24-hour recording, and approximately 2 hours per day full manning for detailed discussion, science checks, and engineering checks of the payload in concert with PSS operations. The PI, PE, and other designated personnel will be on 24-hour call throughout SMS-II.

Normal engineering monitoring will be accomplished in the building 36 SMR.

Voice communications for building 265 will include the flight control loop and the air-to-ground loop as controlled by the payload officer.

2. Consumables and Supplies

° Various consumables and supplies are needed for CRL operations on the flight deck. These items can be stowed on the mid-deck, but it is highly desirable to have those items that are asterisked (*) stowed in the stowage portion of the rear portion of the aft flight deck. The required items are as follows:

1 ea	Hard-bound notebook, at least 10 in. x6 in. and 3/8 in. thick
1 ea	Roll of Scotch® tape with dispenser. Need Scotch® "magic tape" or equivalent.
2 ea	Ball point pens
2 ea	Mechanical pencil with spare lead and erasers
1 ea	Red, green, and black Flair® pens
1 ea	Scissors
1 ea	Yellow, red, blue, and green grease pencils

1 ea	Small Kimwipes®
1 ea	6-in. transparent ruler with scales in inches and centimeters
*1 ea	HP-65 programable calculator with standard pack programs and 12 spare cards, charger
*1 pkg	Graph paper 8-1/2 in. x11 in. with the following amounts of each type: 2 doz 5x5 to in. 1 dox 10x10 to in. 1 doz 5x5 to cm 1 doz 10x10 to cm 1 doz 3-cycle x60 division semilog 2 doz linear x7 days
*1 doz	Packages 8 exposure type 108 color Polaroid® film. Boxes may be stripped but leave film in foil pkg.
*2 doz	Packages 8 exposure type 107 B&W Polaroid® film. Boxes may be stripped but leave film in foil. Fixer not needed as they will be pasted in notebook.
	Trash bags for waste management of above Polaroid® refuse.
*1 ea	Screwdriver with 1/2 in. blade
*1 ea	Phillips head screwdriver with 3/16 in. head

° Stowage Area

Stowage area is needed for the above and also for the following CRL provided items:

2 ea	Polaroid® cameras
12 ea	Extra rack mounting screws
6 ea	Standoffs for CAMAC modules 1 in. x3/4 in. x3/4 in.
1 ea	CRL procedures book 1 in. x12 in. x11-1/2 in.
1 ea	Pocket notebooks, 3 in. x5 in. x1/2 in.

3. Maintenance and troubleshooting are detailed as follows.

° Payload Spares and Repairs

Many functions of the payload have backup systems in the gondola that can be commanded from the aft flight deck. Four functional spares will be carried in the payload which can

be used for modular replacement by a simulated EVA if required. Two of these modules are replacements that will repair payload singe-point failures.

° Aft Flight Deck Spares and Repairs
Four CAMAC module spares will be provided: the Real Time Clock, the NRZ Parallel Input Module, the Dual Output Register, and the Dataway Display.

Most failures have operational workarounds by mixing modes of flight and ground operations. Failure of the PDP-8E could be compensated by real-time decision to use modules from other computers in the spacelab module.

° Flight Deck Spares and Repairs
Could be accomplished outside by CRL personnel as a simulated function of the commander or pilot.

K. Preflight and Postflight Requirements

1. Payload Access

° Preflight

• Day L-1: Preliminary cryogenic and consumables filling time will take about 1 hour. Will need to fill liquid helium, magic gas, liquid nitrogen.

• Hour L-6: Magnet charge will be accomplished with a rollaround mobile power and control (MOPAC) unit. Two power leads and one control cable will be attached to the payload for 1 hour. After this time, care will be taken to keep metals with magnetic susceptibility away from the payload. The area will be roped off to prevent chairs, *et cetera*, from getting close to the 3 T (30 000 gauss) field.

• Hour L-5: Top-off of the consumables in the gondola will be done at this time. Liquid helium, liquid nitrogen, and magic gas filling will be completed prior to L-4 hours closeout.

4.21 (concluded)

- Postflight
  - Day L+3: Access will be required for consumable fill of liquid nitrogen, liquid helium, and magic gas. During a space Shuttle mission, larger tanks for consumables will be in the payload.
  - Day L+6: Depending on the state of consumables, another access may be required for filling.

NOTE

Do not erase data tapes nor subject them to a magnetic field.

2. PSS Access

   Hour L-6: The payload specialist will need access to the aft flight deck from L-6 hours to L-6 minutes to perform preflight checks, and to monitor consumable filling and magnetic charge.

3. CRL Access

   A simulation deviation will be needed for CRL personnel to change the digital tape unit once per day. CRL personnel will have to initiate the tape drive unit after initial power up. These functions will be accomplished on Shuttle by the commander or pilot and can be programed into the flight plan as such.

L. Reporting

TBD in compliance with total mission requirements. Requirements can probably be met by a preliminary report at R+21 and a final report at R+60 days.

M. Training

Crew training

- One crew member will be a Payloads Specialist thoroughly versed in the experiment.
- All other crew members need six hours of training to assist with experiment monitoring.

5.0 OPERATIONAL TEST REQUIREMENTS

The SMS-II OTR's were selected for study to evaluate concepts, methods, operations, and hardware subsystems planned for use in the Life Sciences support of the Shuttle Program.

The OTR's included in SMS-II are directed to the development of medical operations and flight support concepts planned for the Shuttle Program. These studies include Orbiter and Spacelab habitability and equipment and training concepts, in addition to Life Sciences payloads processing.

The results and conclusions gained from these evaluations will be included in the Final Report.

OTR INDEX FOR SMS-II

OTR No.	Title	PI
SMS II-1-OTR	Medical Monitoring	E. C. Burchard, M.D.
SMS II-2-OTR	Shuttle Medical Kit Definition/ Review	E. C. Burchard, M.D.
SMS II-3-OTR	Evaluation of CRT: Hard-Copy Device	B. E. Ferguson
SMS II-4-OTR	Personal Hygiene Planning Concepts	J. B. Westover
SMS II-5-OTR	General Housekeeping and Special Purpose Cleaning and Maintenance Concepts	J. B. Westover
SMS II-6-OTR	Functional Utility of the Orbiter Mid-deck	R. L. Bond
SMS II-7-OTR	Waste Management Mockup	R. L. Sauer
SMS II-8-OTR	Shuttle Biowaste Monitoring System Evaluation	R. L. Sauer
SMS II-9-OTR	Potable Water System	R. L. Sauer
SMS II-10-OTR	Training Flow	M. S. Brzezinski, Jr.
SMS II-11-OTR	Radiation Monitoring	J. V. Bailey
SMS II-12-OTR	Flight Planning Concepts	B. E. Ferguson
SMS II-13-OTR	Shuttle Carry-on Concepts	W. J. Huffstetler
SMS II-14-OTR	Food System	M. C. Smith, D.V.M.

5.1 SMS II-1-OTR. MEDICAL MONITORING

Principal Investigator: E. C. Burchard, M.D.

A. Background/Purpose

The purpose of this requirement is to formalize the medical monitoring approach for the short Shuttle flight and to piece together an appropriate medical evaluation not only of individual crewmembers but of the entire mission.

B. Participants

Participants will include all crewmen, Test Director and, as necessary, other Test Operations Team members who will be required for collection of data and for briefing purposes.

C. Functional Objectives

- To establish the items that will be reported to and discussed with ground-based medical personnel.
- To establish optimum time for the daily medical reports.
- To establish a standardized pattern for obtaining experiment data that has medical relevance.
- To establish an optimum briefing pattern for medical personnel monitoring a flight or calling in to consult on a flight.
- To test the hypothesis that the Test Director may be the optimum briefing point to and after any scheduled or spontaneous medical discussion.

D. Performance Requirements and Conditions

1. Test Operational Requirements

- Preflight (training, support)
  Brief the crew on medical monitoring components. Assist the experimenters in identifying clinically significant data components and the expected reliability of those parameters in the actual testing.

5.1 (continued)

- Provide the crew with an appropriately formatted checklist to record the required test data for a daily status report.
- In-flight (crew requirements, constraints, and frequency)
  Require a daily crew status report (prior to 1700 hours, local time) and a daily medical review between 1800 and 2000 hours.

2. Flight Operations Requirements (crew communications, real-time operational support, and specific data)
   The following will be needed:

   - A site equipped with a tape recorder within the test monitoring room - to permit private medical review (daily and contingency requirements).
   - A medical officer's collection basket for experimental data previously judged as clinically significant. These data must include the date the data are provided to the Surgeon, the date of actual data generation, the quality of the data, any data in processing and when they are to be provided, and any data lost, and why lost.
   - Access to current and projected flight plans for the medical officer.
   - The crew status report for the Medical Officer in either voice transcript or logged on appropriate log sheets by assigned Test Team members.

E. Environmental Requirements

Normal Shuttle cabin environment.

F. Hardware Requirements

None.

5.1 (concluded)

G. System Interface

Intercommunications system, television, and video/audio recording.

H. Data Support Requirements

The following will be required:

1. Preflight (including closeout photos)

   All experiments will be performed to identify clinically significant parameters and the reliability of these, as well as the actual planned collection times: pre-, in-, and postflight.

2. In-flight

   Voice transcripts or correctly completed log sheets containing daily crew status report.

3. The Test Director briefing on the mission status prior to the daily medical review.

I. FDF Requirements

The Flight Plan will reference crew status reports and daily medical reviews.

J. Preflight and Postflight Requirements

(See par. D, Test Operations Requirements.)

K. Reporting

- The Medical Officer or his designated representative will present the crew medical status at the daily TOT meeting.
- A final report will be required within two weeks of test completion.

5.2 SMS II-2-OTR. SHUTTLE MEDICAL KIT DEFINITION/REVIEW

Principal Investigator: E. C. Burchard, M.D.

A. Background/Purpose

The purpose of this requirement is to define an on-board medical capability for Shuttle for both routine monitoring and for contingency purposes. Although not every component will be available for the simulation, it will be assumed that any medical guidance or on-board medical care will be in line with contents as theoretically defined. The assumed capability will be the proposed "less than 7-day package" attached as appendix A.

B. Participants

All crewmen are required to participate. The Medical Officer will work directly with the crew, if any medical kit use is required.

C. Functional Objectives

To evaluate the efficiency of a specified on-board Shuttle medical capability.

D. Performance Requirements and Conditions

For this simulation, actual testing of this system will be done only in the event of a medical contingency requiring this kind of assistance. No specific illness simulation will be planned for this SMS II test.

E. Environmental Requirements

Normal Shuttle cabin environment.

F. Hardware Requirements

An itemized listing of proposed contents of the Shuttle Equipment/Medication Kit is attached as appendix A. It lists the recommended contents for an "up to 7-day" medical kit. Only a

5.2 (continued)

small portion (to be provided by the Medical Officer) will be stowed in the Orbiter mockup.

G. Interface Information

- Location of Hardware (or Software)
  The equivalent of two Orbiter basic storage containers will be designated (or may be simulated only). Each unit will measure 17.9 cm x35.8 cm x53.6 cm (7 in. x14 in. x21 in.). One container will be primarily for the Shuttle medical treatment system, and the other container will be for the Shuttle diagnostic monitoring system - Impedence Pneumograph (ZPN), VCG, HR, cardiac output (CO).
- Mounting Requirements
  A designated work area will be needed for minor medical procedures, with appropriate restraint points; this may be simulated.
- Utility Requirements (electrical, gases, and fluids)
  A minimal refrigeration space will be needed for a 7-day medical capability; this may be simulated.
- Support Equipment Information
  A VCG and ZPN Orbiter transmission and ground reception capability will be needed, but for this simulation these will not be formally tested.
- Other Interface Information
  Other interface information will not be needed as data transmission capability will only be simulated.

H. Data Requirements

1. Preflight

   None.

2. In-flight

   VCG/ZPN capability will not actually be employed; TV for assisting in diagnosis may be employed.

5.2 (concluded)

3. Postflight

None.

4. Data Analysis Support

None.

I. FDF Requirements

The stowage list will list the contents and capabilities of medical treatment and the monitoring system.

J. Preflight and Postflight Requirements

1. Pre-flight

Test Preparation

NA

2. In-flight

° Test Operations

Contingency only.

° Since VCG/HR/ZPN data will not actually be transmitted, the capability to receive such data in the vicinity of the Medical Officer's position may be simulated. A TV in the medical area (for use in assisting diagnoses) will be considered.

K. Reporting

A final report will be required within two weeks of test completion.

L. Training

The Crew will be briefed on medical treatment and monitoring capabilities.

APPENDIX A

PROPOSED CONTENTS OF SHUTTLE EQUIPMENT/MEDICATION KIT

(Minimum Kit designed for Short, *e.g.*, 1-Week, Flights-- (Modeled on IMSS of Skylab but with significant reduction of original IMSS capability.)

Equipment and Basic Supplies

Equipment (presently in prototype physicians bag)

Semi-automatic blood pressure cuff, with digital readout
Digital heart rate readout
Digital respiration readout
Automatic thermometer, digital readout
Strip chart ECG, with harness and leads
Combination oto-, ophthalmoscope
Cassette tape recorder
Penlight
Stethoscope
Minor surgery tray, thoracentesis
Two pair sterile gloves
Suture material, 4 and 00 plain gut
Disposable scalpel
Phone coupler
Finger cots
Two rolls gauze
Two rolled elastic bandages
Two rolls adhesive tape
Two airways
Two intubation tubes
Two light sources for laryngoscope
Laryngoscope
Assorted bandaids and gauze pads
Tuning fork
Reflex hammer, styles, br sh
Tubex dispenser, needle holder
Two 10-cc syringes
Four 22-ga. 1-1/2-in. needles
Two 25-ga. 5/8-in. needles

Drugs

Empty vial, aminophylline
Empty vial, ampicillin
Eye drop, pontocaine hydrochloride® simulated
Ear drops, simulated
Two ampoules $NaHCO_3$
10 ml calcium chloride
Five 2-cc sterile water tubex containers, simulate lidocaine
30 cc ipecac, empty
100 cc benzoin
100 tablets nitroglycerin, empty
100 tablets lanoxin, empty
30 cc distilled water
50 tablets codeine, empty
2 cc hydrocortisone
Five 2-cc sterile water tubex container, simulate/epinephrine

5.3 SMS II-3-OTR. EVALUATION OF CATHODE RAY TUBE (CRT) HARD COPY DEVICE

Principal Investigator: B. E. Ferguson

A. Background/Purpose

For SMS-I, an OTR entitled *CRT Procedures Display System* was written to determine the feasibility of using a CRT as a procedures display medium; to evaluate multiple checklist display formats; and to evaluate procedures updating techniques using a generalized Document processor System (GDP), terminal unit, and hard copy device. The hard copy device used in SMS-I was a Matrix "Versatec", an electromechanical unit which produced a 21.3 cm x27.5 cm (8-1/2x11 in.) paper hard copy presentation of whatever was on the terminal CRT at the push of a button.

Subsequent to SMS-I, the Shuttle Orbiter Change Control Board (CCB) tentatively approved a "Polaroid-type" camera as the hard copy device for the Orbiter.

The purpose of this OTR is to evaluate a "Polaroid-type" camera to determine how useful and effective it will be for making legible hard copies for crew use on board.

B. Participants

All crewmen.

C. Functional Objectives

- To evaluate the ability of crewmen to mount a camera and take satisfactory pictures of a CRT presentation.
- To evaluate adequacy of "Polaroid-type" pictures for operational message updates and permanent records of checklist changes.
- To evaluate different methods of storing "Polaroid-type" pictures for use as operational message updates and checklist changes.

5.3 (continued)

D. Performance Requirements and Conditions

Each crewman will mount a camera to the CRT face and take several pictures using a "Polaroid-type" camera device.

Each crewman will evaluate usefulness of the picture with respect to how well it serves as a hard copy record, *i.e.*, legibility, ease of reading, and markability.

Each crewman will store pictures in a photo album, or tape them on a checklist to evaluate these methods of storage for "Polaroid-type" pictures.

E. Environmental Requirements

Trash disposal of used film packs and film remnants (trash-volume will be included in trash-volume measurement).

F. Hardware Requirements

- CRT device to be photographed.
- A 35 mm camera with Polaroid back.
- A mounting bracket, shield, and waste disposal bag.

G. Interface Requirements

Location of hardware (or software)

- Launch - Stowed (TBD)
- In orbit - mounted to or near multispectral scanner (MSS) CRT

Mounting requirements

Mounting bracket to mount camera to CRT

Utility requirements

None.

5.3 (continued)

Support equipment information

- Film (type TBD)
- Batteries (type TBD)

Other interface information

None.

H. Data Requirements

1. Preflight (including closeout photos)

   Photos of mounted camera from two directions - side view and top or front view.

2. In-flight

   None.

3. Postflight

   Required Polaroid pictures that were taken.

4. Data Analysis Support

   None.

I. FDF Requirements

None.

J. Preflight and Postflight Requirements

1. Preflight

   - To borrow equipment from E&D Directorate.
   - Test Preparation - To test system prior to SMS-II.

2. Postflight

   To evaluate camera, pictures, and mounting bracket.

K. Reporting Requirements

A final report will be required within two weeks of test completion.

5.3 (concluded)

L. Training Requirements

To brief and to demonstrate equipment mounting and picture taking exercises by all crewmen.

5.4 SMS II-4-OTR. PERSONAL HYGIENE PLANNING CONCEPTS

Principal Investigator: J. B. Westover
Co-Principal Investigator: R. J. Marak

A. Background/Purpose

The purpose of this test is to obtain some preliminary evaluation data on:

- The baseline Personal Hygiene System planned for Shuttle.
- Additional personal hygiene items not presently included in the baseline design but exhibiting potential for spacecraft application.

B. Participants

All crewmen will use the personal hygiene provisions for routine personal hygiene functions (hand and body wash, oral hygiene, shaving, *et cetera*).

Principal Investigator and members of the TOT will be required for monitoring, problem solving, reporting and projecting changes for the next simulation.

C. Functional Objectives

- To evaluate effectiveness and crew acceptability of the personal hygiene articles and the personal hygiene station.
- To determine the impact on other systems: Waste Collection System, trash collection, stowage.
- To determine timeline requirements for personal hygiene operations.
- To determine use-rate of expendables.
- To determine characteristics and contents of used wash-water/urine mixture.

- To evaluate effectiveness and crew acceptability of personal hygiene soap.
- To determine water use rate associated with personal hygiene operations.

D. Performance Requirements and Conditions

The personal hygiene system consists of a personal hygiene station and personal hygiene provisions. The personal hygiene station includes a water dispenser and collection device to provide for hands and body wash. The provisions include the personal hygiene kits, washcloths, towels, soap, *et cetera*. Fluid waste from the personal hygiene station is discharged into the Waste Collection System (WCS). The fluid waste characteristics must be compatible with the operation of the WCS centrifuge (fluid wastes should be low-sudsing and relatively free of particulates).

Personal hygiene functions will be accomplished using the personal hygiene system. A record will be maintained to identify each specific use of personal hygiene water and to record time of use. Crewmen will evaluate the adequacy and effectiveness of the system and of a low-sudsing personal hygiene soap to accomplish various personal hygiene functions.

During the simulation, the crew will use voice communications to report problems or deficiencies. Communication with the crew is desired about the middle of the test to determine the status of the personal hygiene station evaluation and to review any problems. At the end of the test, subjective comments will be solicited from the crew pertaining to the effectiveness and acceptability of the personal hygiene system.

E. Environmental Requirements

Normal Shuttle cabin environment.

F. Hardware Requirements

° Personal Hygiene Station

The personal hygiene station will be incorporated in the aft portion of the galley facing the WCS. It will include a hand wash enclosure [approximately 17.5 cm x17.5 cm x22.5 cm (7 in. x7 in. x9 in.)], a mirror, a soap dispenser, controls for water dispensing and temperature adjustment, and miscellaneous piping.

° Personal Hygiene Kits (4 required)

Shaving cream
Styptic pencil
Skin emollient
Stick deodorant
Nail clippers
Hair comb and/or brush
Safety razor and blades or mechanical shaver
Dental floss
Toothbrush
Toothpaste
Anti-chap lipstick

° Miscellaneous

Washcloths (10/man)
Towels (5/man)
Cloth drying restraints (12)
Tissue dispensers (2/man)

G. Interface Requirements

° Location of Hardware

The personal hygiene kits and towel/washcloth assemblies will be stowed on the mid-deck in lockers, in the vicinity of the food galley. The cloth-drying restraints will be mounted to a partition near the aft portion of the galley.

5.4 (continued)

° Mounting Requirements

The thermal flowmeter will be mounted between the Personal Hygiene Station drain and the inlet to the WCS centrifuge.

° Utility Requirements

- Personal Hygiene Station - The personal hygiene station will require ambient and hot water from the galley. The quantity required is estimated at 114.75 kg (2.55 lb) per man/day.
- Thermal Flowmeter Power: 115 V, 400 Hz, 50 W
- Instrument Recorder Power: 115 V, 60 Hz, 10 W

° Support Equipment Information

- A thermal flowmeter will be provided to monitor and record the quantity of water used in the personal hygiene station.

Components	Dimension cm (inches)	Weight kg (lb)
Flow Sensor	26 cm^2 (4 $in.^2$)	0.9 (2)
Heat Sink	14 cm dia. x150 cm long (6 in. dia. x60 in. long)	8.1 (18)
Instrument Package	(47.5 cm x25 cm x10 cm) (10 in. x10 in. x4 in.)	3.6 (8)

° Waste Water Storage Tank - A waste water storage tank will be provided to collect waste liquid (personal hygiene water and urine) from the WCS. The waste water storage tank capacity will be approximately 190 liters (50 gallons).

NOTE

The instrument package, flow sensor, heat sink, and waste water storage tank will be located external to the simulated vehicle.

H. Data Requirements

1. Preflight

- Closeout photos of the personal hygiene station, the cloth-drying constraints, and general stowage of personal hygiene provisions.
- An inventory of personal hygiene provisions, and stowage weights and volumes.

2. In-flight records will be maintained on the following:

- Problems and deficiencies as reported by the crew.
- Deviations from personal hygiene timeline allotments.
- Identification of specific uses of personal hygiene water and recorded time of use.

3. Postflight the following will be compiled:

- An inventory of remaining personal hygiene provisions.
- A summary of problems, deficiencies, and timeline deviations.
- A completed personal hygiene station evaluation questionnaire.

4. Data Analysis

None required.

I. FDF Requirements

- Personal hygiene station procedures.
- Personal Hygiene Station Evaluation Questionnaire.

J. Test Operations Requirements

1. Preflight

The crew will be familiarized with personal hygiene provisions and with plans to evaluate the personal hygiene station. Personal hygiene provisions will be inventoried prior to the test. Stowage weights and volumes will be recorded.

5.4 (concluded)

2. In-flight

- Test Preparation - none required.
- Test Operations
  - The crew will use the personal hygiene provisions for routine functions.
  - The personal hygiene station will be used to support personal hygiene functions as required. At a minimum, the system will be used for hands and body wash. Other functions will be accomplished contingent upon their compatibility with the Waste Collection System. This will include such functions as utensil washing, shaving, razor cleaning, brushing teeth, washing or wetting of hair, and mouth rinse.
  - The crew will use the SMS-II timeline schedule to perform daily personal hygiene functions. Deviations from the timeline will be reported using the Voice Communications System.
  - Equipment problems or deficiencies will be reported by means of the Voice Communications System.

3. Postflight

- Subjective comments will be solicited from crewmen pertaining to the effectiveness and acceptability of the personal hygiene provisions.
- An inventory of the personal hygiene provisions will be obtained post-test to determine use rates of expendables.

K. Reporting

A final report will be required within two weeks of test completion.

L. Training

Crew familiarization with systems operation, troubleshooting, and maintenance procedures.

5.5 SMS II-5-OTR. GENERAL HOUSEKEEPING AND SPECIAL PURPOSE CLEANING AND MAINTENANCE CONCEPTS

Principal Investigator: J. B. Westover
Co-Principal Investigtor: R. L. Sauer

A. Background/Purpose

The purpose of this test is to obtain preliminary evaluation data on:

- The baseline general housekeeping, cleaning, and maintenance requirements planned for Shuttle.
- Selected housekeeping/cleaning concepts not presently included in the baseline design, but exhibiting potential for Shuttle application.

B. Participants

- Number of Crewmen

  All crewmen will perform general housekeeping tasks.

- Function of Crewmen

  Crewmen will utilize procedures and provisions for general housekeeping, cleaning, and maintenance operations.

- Test Operations Team

  Principal Investigators and members of the TOT are required for monitoring, problem solving, reporting and projecting changes for the next simulation.

C. Functional Objectives

- To evaluate general effectiveness and crew acceptability of general housekeeping, cleaning and maintenance procedures and provisions.
- To determine adequacy of trash handling provisions.
- To determine timeline requirements for general housekeeping, cleaning, and maintenance operations.

- To determine use rate of expendables.
- To identify special or unique cleaning/maintenance problems associated with science experiments.
- To assess adequacy of stowage provisions for equipment, expendables, and trash.

D. Performance Requirements and Conditions

General housekeeping/cleaning tasks will be accomplished using housekeeping procedures and provisions.

Emphasis will be placed on trash-handling provisions, adequacy of timeline allotment, and identification of special or unique cleaning/maintenance problems associated with the test experiments. Subjective comments will be solicited from the crewmen post-test pertaining to the adequacy and effectiveness of the housekeeping/maintenance procedures and provisions. The crew will use voice communications to report problems or deficiencies.

E. Environmental Requirements

Normal Shuttle cabin environment.

F. Hardware Requirements

- Apollo-type vacuum cleaner
- General purpose wipes (4 dispensers off-the-shelf)
- Sanitation agent (2 dispensers)
- Trash bags (for dry storage) (total of 13)
- Large dry-storage trash bag (supplied by Crew Systems Division)
- Gloves, plastic disposable (off-the-shelf)
- Wet-trash stowage compartment (vented)
- 24-hour wet-waste stowage containers (18)

G. Interface Requirements

° Location of Hardware

- The general purpose wipes, sanitation agents, and gloves will be stowed in lockers on the mid-deck in the vicinity of the galley.
- Large dry-storage trash bag - TBD.
- Vacuum cleaner - TBD.
- Dry-storage bags - one will be located in the payloads bay and one on the mid-deck.
- Twenty-four-hour wet-waste stowage containers - launch stowage in lockers on the mid-deck in the vicinity of the galley. Use locations: One in the payloads bay and one on the mid-deck.
- Wet-trash stowage vented compartment - to be located on the mid-deck in the vicinity of the sleep station.

° Mounting Requirements

- Mating hardware is required to mount trash bag snaps.
- The wet-trash stowage compartment will be connected to the inlet line to provide for venting.

° Utility Requirements

Vacuum cleaner - 115 V, 400 cycle

H. Data Requirements

1. Preflight
   - ° Closeout photo(s) of housekeeping provisions stowage.
   - ° An inventory of housekeeping provisions, stowage weights and volumes will be compiled.

2. In-flight records will be maintained on the following:
   - ° Problems and deficiencies as reported by the crew.
   - ° Deviations to general housekeeping timeline allotments.
   - ° Deviations to the planned disposal of expendables.

3. Postflight

   - An inventory of remaining housekeeping provisions.
   - A summary of problems, deficiencies, timeline deviations, stowage list deviations, and used expendable disposal deviations.
   - Results of the microbiological sampling.

4. Data Analysis

   None required.

I. FDF Requirements

1. Housekeeping procedures.

2. Microbiological sampling procedures.

J. Test Operational Requirements

1. Preflight

   Requires that crew be familiarized with housekeeping provisions procedures, and with plans for evaluation of the housekeeping system. Housekeeping provisions will be inventoried prior to the test. Stowage weights and volumes will be recorded.

2. In-flight

   - Test Preparation - Procedures for in-flight microbiological test preparations will be included in FDF requirements.
   - Test Operations
     - The crew will accomplish general housekeeping/cleaning tasks using the housekeeping provisions and procedures.
     - Equipment problems or deficiencies will be reported by means of voice communications system.

- The crew will use the SMS-II timeline schedule to perform general housekeeping cleaning and maintenance tasks. Deviations from the timeline will be reported using the voice communications system.
- The on board crewmen will evaluate one or more sanitation agent and technique. Evaluation criteria will include cleaning effectiveness, odor characteristics, agent removal (wipe-off) characteristics, task simplicity, expendable requirements, *et cetera*.
- Microbiological samples will be taken at specified locations to verify effectiveness of the sanitation procedures.

3. Postflight

- Subjective comments will be solicited from crewmen pertaining to the adequacy and effectiveness of the housekeeping/maintenance procedures and provisions.
- An inventory of the housekeeping provisions will be obtained postflight to determine use rates of expendables.

K. Reporting

A final report will be required within two weeks of test completion.

L. Training

Crew familiarization with the system.

5.6 SMS II-6-OTR. FUNCTIONAL UTILITY OF THE ORBITER MID-DECK

Principal Investigator: R. L. Bond
Co-Principal Investigator: M. L. Johnson

A. Background/Purpose

The purpose of this OTR is to evaluate the adequacy of man-machine engineering provisions within the mockups used to conduct the simulation and, where possible, to isolate problems of functional utility and man-machine interfaces to allow design assessments and recommendations.

B. Participants

All crewmen involved in the simulation will be direct or indirect contributors.

C. Functional Objectives

- To evaluate the functional utility of the Orbiter mid-deck.
- To evaluate the man-machine engineering provisions of the Spacelab mockup.

D. Performance Requirements and Conditions

No special requirements.

E. Environmental Requirements

Normal Shuttle cabin environment.

F. Hardware Requirements

None.

G. Interface Requirements

None.

H. Data Requirements

Possible postflight questionnaire.

5.6 (concluded)

I. FDF Requirements

None.

J. Preflight and Postflight Requirements

1. Preflight

None.

2. Postflight

Possible administration of postflight questionnaire.

K. Reporting Requirements

A final report will be required within two weeks of test completion.

L. Training Requirements

Identify non-baseline mockup configuration items for the crewmembers.

5.7 SMS II-7-OTR. WASTE MANAGEMENT MOCKUP

Principal Investigator: R. L. Sauer

A. Background/Purpose

To simulate the operational and performance characteristics of the baseline Shuttle Orbiter Waste Management System and in so doing, obtain evaluations regarding procedures and acceptability of the system.

B. Participants

All crewmembers will use the system for defecations and micturitions during SMS-II test activities.

C. Functional Objectives

To collect and process crewmember metabolic wastes (feces and urine).

D. Performance Requirements and Conditions

- All system/user interfaces will be identical or similar to those planned for the Shuttle Orbiter.
- A "dry-john"-type system complete with vacuum drying and odor controlled venting will be used.
- The system will be capable of accommodating all crewmember defecations and drying all feces collected.
- Pneumatic collection with subsequent phase separation by centrifugation will be provided for urine management. Urine disposal will be into a waste water tank. This tank will also collect waste water from the personal hygiene station.

E. Environmental Requirements

The system can operate in any environment acceptable for crewmember "shirtsleeve"-type operations.

F. Hardware Requirements

- "Dry-john"-type fecal collector
- Shuttle-designed seat
- Odor control filter and fan
- Shuttle-type urinal, flex hose, phase separator pump, Urine Disposal System

G. Interface Information

- Location of Hardware - TBD.
- Mounting Requirements - TBD.
- Utility Requirements (electrical, gases, fluid, *et cetera*).
  - Power: 28 Vd.c. ±4 V 60 W
    400 Hz 115/200 Va.c. 3-phase 65 W
  - Vacuum for feces drying: System must be capable of Maintaining 13.8 N/m^2 (0.002 psia) against a sealed system volume of 0.085 m^3 (3 ft^3) and must be able to pump a mass equivalent of 1000 g per day water vapor.
- Support Equipment Information

  Urine system operation requires a waste urine tank for disposal of urine and flush water. This tank will also be used for disposal of personal hygiene waste water.
- Other Interface Information

  This system will functionally interface with the Biowaste Monitoring System (BMS) allowing simultaneous use of both systems.

H. Data Requirements

1. Preflight

   None.

2. In-flight

   Crew comments and logs.

5.7 (concluded)

3. Postflight

Crew debriefing comments.

4. Data Analysis Support

None.

I. FDF Requirements

Crew Procedures document.

J. Test Operational Requirements

1. Preflight

Pretest system performance evaluation is required to verify satisfactory operation of the system.

2. In-flight

° Test Preparation - no equipment preparation is required other than system activation.

° Test Operations - no requirement other than normal use by the crew.

3. Postflight

No requirements.

K. Reporting

A final report will be required within two weeks of test completion.

L. Training

Crew familiarization with the system.

5.8 SMS II-8-OTR. SHUTTLE BIOWASTE MONITORING SYSTEM EVALUATION

Principal Investigator: R. L. Sauer

A. Background/Purpose

To support proposed Shuttle biomedical and diagnostic experiments, a means is required to measure the volume and to collect representative samples from the micturitions of selected crewmembers. The BMS is designed to perform these functions.

B. Participants

A number of participants is TBD. All crewmembers will use the system for micturitions; however, only selected crewmembers will collect urine samples at a TBD rate.

C. Functional Objectives

- To automatically measure in real-time the volume of each micturition of each selected crewmember.
- To collect a 20 ±5 ml sample with system user option.
- To provide user identifiable samples with this system.

D. Performance Requirements and Conditions

- System Performance
  - The system's volume measurement accuracy will be within 2 percent.
  - Chemical cross-contamination from sample to sample will be no greater than 0.5 ml.
  - The system will accommodate male and female users.
  - The urinal will be usable for standup or seated position.
  - For female use, the urinal assembly will be a contact-type and will be fitted with an individualized contact interface.

- Test Operations

  A graduated cylinder will be provided so that selected urine void volumes may be determined. Following void volume determination, the urine will be processed in the BMS.

- Flight Operational Requirements

  - On those occasions when an intermediary graduated cylinder is used for volume determination, the observed value will be communicated to the PI or appropriate representative.
  - Flush tank daily. Refill.

E. Environmental Requirements

The system can operate in any environment acceptable for crew-member "shirtsleeve"-type operations.

F. Hardware Requirements

- BMS Module
- Urinal with flex hose
- Urinal interface caps
- Urine sample containers
- Interconnecting hoses

G. Interface Requirements

- Location of Hardware

  Vertical free space - a minimum of 25 cm x25 cm x60 cm (10 in. x10 in. x24 in.) above the BMS instrument - is required for access to the system controls.

- Mounting Requirements

  The BMS will be securely mounted so that it is not dislodged during use or sample container changeout.

- Support Equipment Information

  Flush water supply tank with 5-liter capacity is required. The tank will be refilled daily with facility potable water.

° Other Interface Information

The BMS will interface with the Shuttle Orbiter WCS mockup. The WCS shall provide transport airflow for the BMS.

H. Data Requirements

1. Preflight

No requirements.

2. In-flight

Urine volume data from each micturition will be recorded on teleprinter tape in the science console area.

3. Postflight

No requirements.

4. Data Analysis Support

Biomedical analyses results will be compared with urine volume and metabolic balance data by Biomedical Research Division personnel.

I. FDF Requirements

° Crew Procedures document
° Urine sample identification data

J. Preflight and Postflight Requirements

1. Preflight

° Pretest system performance evaluation is required to verify volume measurement accuracy.

° Crew training in systems operation and sample changeout.

2. In-flight

Test preparation - no equipment preparation is required unless urine samples are to be obtained. If urine is to be sampled, each crewmember will install a sample container prior to the micturition to be sampled.

3. Postflight

No requirements.

K. Reporting Requirements

A final report will be required within two weeks of test completion.

L. Training Requirements

Crew orientation and systems operation briefing and checkout.

5.8A SMS II-8(A)-OTR. SHUTTLE BIOWASTE MONITORING SYSTEM EVALUATION

Principal Investigator: R. L. Sauer

A. Background/Purpose

The purpose of this test is to verify system operation in the collection, measurement, and sampling of urine and to determine the amount of cross-contamination between urine voids.

Note: SMS-II-8-OTR (reference page 175) establishes the operational requirements for the Biowaste Monitoring Systems definition. This OTR provides further definition of preflight and in-flight operational requirements and evaluations.

B. Participants

1. Number of crewmen

   All crewmen will use the system during a 24-hour test period.

2. Function of the crewmen

   The crewmen will use the system for urine collection, sampling, volume measurement and process during a 24-hour period.

3. Test/Operations Team

   - PE of demonstration equipment
   - Test Operations Team

4. TBD Analysis Laboratory personnel

C. Functional Objectives

- To determine cross-contamination between individual voids.
- To determine system's void volume measurement accuracy.
- To determine system's ability to collect a representative sample from each void.
- To obtain crew comments on system performance.

5.8A (continued)

D. Performance Requirements and Conditions

One 24-hour test period after Day 3 will be designated. Each crewman throughout the 24-hour period will use the BMS for all urine collections. The 24-hour period will begin after the first void of the morning, continue to the next day and include the first void of that day.

Each void will be initially collected in a graduated cylinder (one cylinder for each crewman). Approximately 20 ml of urine will be decanted into a 50 ml Falcon® urine sample container. The sample container will be marked with crewman name, time, and the remaining urine volume in the graduated cylinder after the sample is withdrawn. The remaining urine in the cylinder will be dumped into the BMS urinal. Normal BMS procedures will be used to obtain another sample and measurement of the volume. The two samples will then be placed in the freezer and frozen for postflight analysis.

One crewman will be injected with tritium after his first void of the test day. Cross-contamination will be tested by checking for residual tritium in the other crewmembers' samples.

E. Environmental Requirements

No constraints. System can operate in any environment acceptable for crewmember shirtsleeve operations.

F. Hardware (or Software) Identification and Description

- Biowaste Monitoring System
- Individualized 500 ml graduated cylinders - 3
- 50 ml Falcon® urine sample containers - 24
- BMS sample containers - 24

G. Interface Information

- Location of Hardware (or Software)

  TBD

5.8A (continued)

- Mounting Requirements

  N/A

- Utility Requirements (Electrical, Gases, Fluids, *et cetera*)

  N/A

- Support Equipment Information

  N/A

- Other Interface Information

  Freezer space is needed to store samples.

H. Data Support Requirements

The following will be required.

1. Preflight

   (Including close-out photos)

2. In-flight

   BMS data print-out after use

3. Postflight (Data Retrieval, Special Handling, DTU Access, *et cetera*)

   Transport of urine samples to analysis laboratory.

4. Data Analysis Support

   Report from analysis laboratory containing
   - Cross-contamination from BMS.
   - Sample quality.

I. FDF Requirements

N/A

J. Test Operational Requirements

1. Preflight (Training, Support, *et cetera*)

   TBD crew training

5.8A (continued)

2. In-flight (Crew Requirements, Constraints, Frequency, *et cetera*)

   a. Test Preparation

      ° Selection of one crewmember for tritium injection.
      ° Designation of time period (after day 3) of test period.

   b. Test Operations

      ° Inject selected crewmember with tritium.
      ° Collect each void in graduated cylinders.
      ° Extract a sample and measure volume left in cylinder.
      ° Pour remaining urine into BMS urinal (approximate normal voiding rate).
      ° Collect a sample and measure volume using BMS.
      ° Store both samples for postflight analysis.

3. Postflight

   ° Laboratory analysis of urine samples
   ° Obtain crew comments during postflight debriefing.

4. Flight Operational Requirements (Crew Communications, Real-time Operational Support, Specific Data, *et cetera*)

   N/A

5.9 SMS II-9-OTR. POTABLE WATER SYSTEM

Principal Investigator: R. L. Sauer

A. Background/Purpose

To support various crew activities and metabolic requirements during SMS-II, Shuttle-type potable water will be provided by the Potable Water System. To simulate the operational and performance characteristics of the baseline Shuttle Orbiter water management system will permit evaluation of the water system and its components.

B. Participants

All crewmembers will use the system for potable water requirements.

C. Functional Objectives

To supply water of similar quality as that provided by the Shuttle fuel cells.

D. Performance Requirements and Conditions

- Water delivered by the system will be of quality as good as that specified for Shuttle potable water.
- Delivered water temperature will be 7.2 ± 4 °C (45 ± 4 °F) from the chilled water outlet.
- System pressure will be maintained at 8.3×10^4 (-3 to +4) N/m^2 [12 (-3 to +4) psig].

E. Environmental Requirements

The system can operate in any environment acceptable for crewmember "shirtsleeve"-type operations.

F. Hardware Requirements

- A single water storage tank simulating Shuttle Orbiter tankage will be provided.

- Refrigeration for the chilled water will be provided by a commercial water cooler.
- Facility water system pressure regulated to 8.3×10^4 (-3 to +4) N/m^2 [12 (-3 to +4) psig] will provide pressurization for the mockup system.

G. Interface Information

- Location of Hardware (or Software)

  TBD.

- Mounting Requirements

  Water distribution lines and connectors will be similar.

- Utility Requirements

  The source of the water supply for the system will be JSC facility water.

- Support Equipment Information

  Shuttle quality water will be obtained by processing facility water through a commercial Millipore Corporation (Bedford, MA) Super-Q device.

- Other Interface Information

  Two interfaces with an option for a third will be provided. One each of ambient and chilled water interfaces will be provided to the galley. A third interface option will be provided for future use.

H. Data Requirements

1. Preflight

   Water analysis report from laboratory.

2. In-flight

   Crew log entries and crew briefing comments.

5.9 (concluded)

3. Postflight

Water analysis report from laboratory.

4. Data Analysis Support

None.

I. FDF Requirements

None.

J. Test Operational Requirements

1. Preflight

- Pretest system performance evaluation is required to verify water quality and delivery rates.
- Crew familiarization with equipment is required. No detailed training procedures are necessary.
- Preflight system sterilization will be accomplished using planned Shuttle procedures.

2. In-flight

- Test Preparation - no requirements.
- Test Operations - no requirements.

3. Postflight

Water sample(s) will be taken to verify quality and system performance.

K. Reporting

A final report will be required within two weeks of test completion.

5.9A SMS II-9(A)-OTR. POTABLE WATER SYSTEM

Principal Investigator: R. L. Sauer

A. Background/Purpose

The purpose of this test is to verify that the potable water system to be used on the Life Sciences Spacelab Mission Simulation Test II will deliver potable water meeting the established chemical and microbiological requirements.

Note: SMS-II-9-OTR (reference page 179) establishes the operational requirements for the Potable Water System. This OTR provides further definition of preflight and in-flight operational requirements and evaluations.

B. Participants

1. Number of crewmen

   Three.

2. Water servicing technicians

   TBD

3. Analysis laboratory personnel

   TBD

C. Functional Objectives

- Evaluate procedures for sterilizing water system.
- Evaluate microbiological and chemical quality of delivered water.
- Evaluate operation of silver ion generator.
- Obtain crew comments on water delivery and taste.

D. Performance Requirements and Conditions

Four series of samples will be taken for chemical and microbiological analysis:

1. During servicing [approximately three (3) weeks prior to test start].

5.9A (continued)

2. Just prior to test start.

3. During test.

4. Post-test.

All samples should meet the specifications outlined in SE-S-0073B, *Space Shuttle Fluid Procurement and Use Control Specification*. In addition, a microbiological series of samples will be obtained prior to sterilization of the system.

Crew comments will be obtained during the test and postflight debriefing concerning the palatability, temperature, and flow rates of the system delivered water.

E. Environmental Constraints

No constraints. The system can be operated in any environment acceptable for crewmember shirtsleeve operations.

F. Hardware (Software) Identification and Description

These requirements will be defined in appropriate Test Preparation Sheets (TPS's), *i.e.*, water system servicing TPS and water sampling TPS.

G. Interface Information

° Location of Hardware (or Software)

Sample parts will be located and numbered per BE-00018, SMS-II *Water System Schematic*.

° Mounting Requirements

N/A

° Utility Requirements

N/A

° Support Equipment Information

a. Chlorine solution mixing and injection tanks
b. Standard microbiological and chemical sampling apparatus

5.9A (continued)

° Other Interface Information

N/A

H. Data Support Requirements

1. Preflight

None

2. In-flight

None

3. Postflight

None

4. Data Analysis Support

Chemical and microbiological analysis of water samples.

I. FDF Requirements

N/A

J. Test Operational Requirements

1. Preflight (Training, Support, *et cetera*)

Three series of samples will be taken at TBD sample ports. The first series will be microbiological samples only, taken prior to system servicing. The second series will be chemical and microbiological samples taken immediately after system servicing. The third series of samples will be chemical and microbiological samples taken just prior to test start.

2. In-flight (Crew Requirements, Constraints, Frequency, *et cetera*)

a. Test Preparation

N/A

b. Test Operations

One series of chemical and microbiological samples will be taken external of the Orbiter (no crew impact) at TBD test points.

5.9A (continued)

c. Daily Samples to determine silver level

3. Postflight

One series of chemical and microbiological samples will be taken at TBD test points.

4. Flight Operational Requirements

No requirements.

5.10 SMS II-10-OTR. TRAINING FLOW

Principal Investigator: M. S. Brzezinski, Jr.

A. Background/Purpose

The purpose of this test is to demonstrate and evaluate the Systems Approach to Training (SAT) and the short-term training of a crew selected from multidiscipline populations.

B. Participants

Crewman and TOT; Training Manager; experiment PI's and PE's.

C. Functional Objectives

- To develop the tasks and analyses required for the training to support the experiments approved for the test.
- To evaluate the short training cycle proposed for Shuttle crewmen.
- To evaluate the team concept of mission training as outlined in the *Skylab Terminal System Biomedical Operations Plan*.

D. Performance Requirements and Conditions

- Briefings and seminars will be given by the PI and PE on each experiment in their respective laboratories. The in-depth training given the flight crew will be more than that given to the TOT.
- The flight crew will practice the performance of the experiment and use of the associated equipment. The preliminary performance will be in the respective PI's laboratory after which it will be executed in the Life Sciences Payload's Facility (LSPF).

- The flight crew should reach a level of competence to enable them to perform all experiments from on board FDF procedures. The TOT should have sufficient knowledge of the experiments to coordinate real-time changes in the FDF where necessary.

E. Environmental Requirements

Normal Shuttle cabin environment.

F. Hardware Requirements

To conduct training, test and experiment development equipment will be used.

G. Interface Information

None.

H. Data Requirements

Weekly training schedules will be required pretest. These will be maintained by the Training Manager.

I. FDF Requirements

Only those documents required for support of the test will be required for training. Pretest copies of all FDF documents will be required at approximately T-75 days.

J. Test Operational Requirements

1. Preflight

   No additional requirements.

2. Postflight

   An evaluation by the TOT and crewmen will be included in the final report.

K. Reporting

A final report will be required within two weeks of test completion.

L. Training Requirements

A Training Plan will document training requirements and schedules.

5.11 SMS II-11-OTR. RADIATION MONITORING

Principal Investigator: J. V. Bailey

A. Background/Purpose

Radiation dose limits for manned space flight are established for each mission, utilizing a "risk versus gain" philosophy recommended by a Committee of the National Academy of Sciences. The radiation hazard is equated with other potential hazards of space operations and is acceptable if justified by an appropriate gain. Recommendations regarding limits for each mission are made by the JSC Radiation Constraints Panel. The purpose of this requirement is to define crew involvement time, stowage needs, and recovery hardware.

B. Participants

All crewmen.

C. Functional Objectives

- To maintain an updated radiation history on each crewman.
- To alert Mission Control and crewmen to excessive radiation levels.
- To alert Mission Control and crewmen to excessive radiation dosages.
- To evaluate proposed Personal Radiation Dosimeter (PRD) storage locations in the Orbiter and Spacelab Mockups.

D. Performance Requirements and Conditions

During Shuttle missions, each crewman will be assigned an individual PRD. Each PRD will also have a designated storage location in the Orbiter or Spacelab when not being worn. In addition to evaluating proposed operational aspects of radiation monitoring for Shuttle, the proposed locations for the PRD's will be evaluated during SMS-II.

5.11 (concluded)

E. Environmental Requirements

- System can be operated in any environment consistent with crewmember "shirtsleeve"-type operation.
- All sources of radiation in the test area will be identified and evaluated by the Environmental Health Branch prior to the simulation.

F. Hardware Requirements

The PRD's and appropriate storage mountings will be provided by the Environmental Health Branch. Mounting locations and attachment fittings will be required in the Shuttle and Spacelab mockups.

G. Interface Requirements

Location and means for attaching PRD storage mountings TBD.

H. Data Requirements

- Crew comments and log notes will be required.
- PRD readings will be taken every 24 hours and are to be included in the crew Medical Status Report.

I. FDF Requirements

Crew Procedures document.

J. Test Operational Requirements

TBD.

K. Reporting

A final report will be required within two weeks of the completion of the test.

L. Training

Crew familiarization with system and assigned PRD locations.

5.12 SMS II-12-OTR. FLIGHT PLANNING CONCEPTS

Principal Investigator: B. E. Ferguson

A. Background and Purpose

Previous space flights have involved extensive premission and real-time flight planning. The objective of this OTR includes the identification and development of planning concepts to simplify and expedite this process for Shuttle missions.

The purpose of this requirement is to develop and evaluate Shuttle flight planning concepts with respect to premission and real-time planning.

For the purposes of this OTR, premission flight planning includes:

- Obtaining scheduling data and constraints for premission and real-time planning.
- Correlating Flight Plan activities with crew procedures.
- Evaluating mission alternatives to maximize mission payload return (*e.g.*: length of mission, number of crewmen, experiment trade-offs, *et cetera*).
- Integrating Orbiter and payload activities into a Flight Plan.

Real-time flight planning includes:

- Maintaining and revising Flight Plans as required (ground).
- Communicating Flight Plan changes to crew (voice, teleprinter, CRT, *et cetera*).
- Planning involvement by crew.

B. Participants

All crewmen and all members of the TOT.

5.12 (continued)

C. Functional Objectives

- To develop and evaluate a basic crew day for a Spacelab/pallet payload mission.
- To develop an integrated Flight Plan including Orbiter and payload operations and to identify interfaces and constraints.
- To develop criteria for determining mission profile by use of Flight Plan studies and/or other means of determining limiting factors.
- To develop Calcomp (California Computer Corporation) plotter formats for use by the test team and to develop crew Flight Plan formats (paper).
- To develop CRT Flight Plan formats and evaluate use by crew during TBD days of the test (ref. SMS II-3-OTR).
- To develop real-time planning interface between crew and ground.
- To determine the feasibility of designating some real-time functions to the crew
- To develop two-shift crew Flight Plans.

D. Performance Requirements and Conditions

- To evaluate what type of real-time planning can be accomplished on board the vehicle on at least one day of the test.
- To define a basic crew day, *i.e.*, the daily required activities - eating, post- and presleep activities, housekeeping duties, medical status, mission status, *et cetera*. The remaining time will be allocated to payload and Orbiter operations.
- To determine the mission profile to include such factors as length of mission, number of crewmen, crew shifts, *et cetera*.
- To evaluate the multiple Flight Plan formats on at least one day of the test, using the CRT to display the Flight Plans.

5.12 (concluded)

E. Environmental Requirements

Normal Shuttle cabin environment.

F. Hardware Requirements

- CRT Hard Copy Device
- Voice Intercom
- Teleprinter

G. Interface Information

None.

H. Data Requirements

- Crew Logs
- Debriefing
- Planner Logs

I. FDF Requirements

Crew Flight Plan.

J. Test Operational Requirements

Crewmembers and ground personnel using the CRT terminal need to be knowledgeable of the system operation.

K. Reporting

A final report will be required within two weeks of test completion.

L. Training Requirements

None.

5.13 SMS II-13-OTR. SHUTTLE CARRY-ON CONCEPTS

Principal Investigator: W. J. Huffstetler

A. Background/Purpose

A number of individual experiments flown on the Shuttle will be of the "carry-on" type. This category of payload will feature standard mounting provisions and minimal systems interface requirements to simplify operational impact.

The purpose of this requirement is to define methods of selecting, processing, and integrating "carry-on" payloads into the Orbiter and to evaluate the operational impact of this type of payload.

Two of the experiments proposed for SMS-II are of the "carry-on" type:

- *The Effect of Orbital Shifts on Cardiovascular Dynamics*
- *The effect of Zero-g Fluid Shifts on the Vectorcardiogram*

B. Participants

All crewmen.

C. Functional Objectives

- To establish methods of selecting and processing Shuttle "carry-on" payloads.
- To define the pre- and post-test equipment processing cycle, shipment schedule requirements, interface requirements, mounting provisions, internal inspection, and qualification requirements.
- To define the timeline impact and Flight Plan requirements generated by "carry-on" payloads.
- To establish stowage methods, logistics planning, maintenance, and troubleshooting requirements.
- To investigate data processing requirements associated with "carry-on" payloads.

5.13 (continued)

D. Performance Requirements and Conditions

1. Preflight

To brief the crew on position and function of "carry-on" experiment devices, and to detect indications of abnormal operation. Crew will be required to understand all systems and operational interfaces.

2. In-flight

- To verify power ON and to status periodic checks on passive experiments, with possible crew participation as subject.
- To evaluate impact of "carry-on" type experiments by crew.

3. Postflight

- To recover data.
- To remove and return equipment.

E. Environmental Requirements

Normal Shuttle cabin environment.

F. Hardware Requirements

Standard mounting location and attachment in Orbiter Lower Deck.

G. Systems Interface

- Electrical Power
- Gases
- Waste Disposal
- H_2O

H. Data Support Requirements

TBD

I. FDF Requirements

The Flight Plan will include "carry-on" experiment items, trouble-shooting procedures and anomaly detection instructions.

5.13 (concluded)

J. Test Operational Requirements

TBD

K. Reporting

A final report will be required within two weeks of test completion.

L. Training

None.

5.14 SMS II-14-OTR. FOOD SYSTEM

Principal Investigator: M. C. Smith, D.V.M.
Co-Principal Investigator: R. M. Rapp

A. Background/Purpose

This system provides for nutrient and energy requirements for crewmembers. Throughout previous programs other mission activities and work schedules have precluded adequate time for meal preparation and food consumption. The purpose of this requirement is to evaluate:

- Timelines,
- Food system - galley system interfaces, and
- Accessory items.

B. Participants

All crewmen will participate.

C. Functional Objectives

- To evaluate the efficiency of galley system concept for food preparation and service using one individual to prepare all meals. (Crew preference and crew timelines may determine who performs this duty, *i.e.*, a different crewman each meal or each day).
- To establish timeline requirements for food preparation and consumption for subsequent comparison to proposed flight-type system.
- To evaluate utensil cleaning using commercial wet wipes.
- To evaluate use and efficiency of hot pads.

D. Performance Requirements and Conditions

The SMS-II Food System consists of a seven-day food supply for three men. On test day 1, two meals will be provided for each crewman. On other days, three meals per crewman and a pantry

containing snacks and beverages and accessory items will be provided. The meals and pantry will be stowed in two standard lockers.

Menus will be the same for all crewmen and provide approximately 2800 kilocalories (Kcal) per man per day. Three meals will be contained in each meal overwrap. Meal packages will be identified with Day and Meal designations. One crewman will prepare all meals in the galley, *i.e.*, rehydration, heating, *et cetera*, and place item(s) on serving tray for the other crewmen. The pantry may be used to substitute or supplement standard menus. Crew will use voice communication to report any problems or deficiencies. Crew will report menu food deviation and water consumption as part of the Daily Status Report.

E. Environmental Requirements

Normal Shuttle cabin environment.

F. Hardware Requirements

° Food System

Meal packages and pantry foods will be stowed in two standard lockers on the mid-deck.

° Accessory Items

The following items will be stowed in the galley:

Utensils	Hot pads
Scissors	Vitamins
Can openers	Germicidal tablets
Spice kit	Drinking water dispenser
Chewing gum	Wet wipes

G. Interface Requirements

° Meal stowage in mid-deck lockers
° Accessory item stowage in galley

- Food package rehydration valve interface with food preparation equipment
- Food interface with galley oven
- Food interface with serving tray
- Wet and dry trash stowage

H. Data Support Requirements

On board menu logs.

I. FDF Requirements

- Meal periods will be allocated in the Flight Plan.
- Menus will be located at the Flight Data File/Flight Plan.
- Cue cards will be provided with menu and food preparation instructions.

J. Test Operational Requirements

1. Preflight

Crew training on food package configurations, and preparations. This will be done separately and in conjunction with galley familiarization and function.

2. In-flight

Maintain on-board logs of food and water consumption.

3. Postflight

- Crew debriefing with subjective comments on the food system.
- Inventory of remaining food components.

4. Data Analysis

Calculate energy intakes.

L. Reporting

A final report will be required within two weeks of test completion.

5.14 (concluded)

M. Training

Crew debriefings on food package configuration, food preparation, and clean-up. Also, food package interface with galley system and functional operation.

5.15 SMS II-15-OTR. DEFINE AND EVALUATE PAYLOADS PROCESSING

Principal Investigator: S. M. Luczkowski
Co-Principal Investigator: F. R. Spross

A. Background/Purpose

In order to satisfactorily meet the proposed Shuttle mission turnaround schedule, a well organized and executed method of experiment and payload processing will be required.

The purpose of this OTR is to define, develop, and evaluate improved methods whereby JSC experiments for Shuttle will be selected, integrated, and checked out prior to being forwarded for inclusion into the final mission package.

B. Participants

Participants will include members of the Mission Management Board, TOT, Flight Crew, Payloads Review Team, LSD Science Review Committee, and Flight Planning Review Team.

C. Functional Objectives

To identify and evaluate payloads processing requirements from experiment selection through integration and checkout, including:

- Methods of experiment selection.
- Single or multiple experiment test facility utilization.
- Prelaunch access timeline constraints.
- Methods of experiment arrangement.
- Removable floor segment/rack configuration definition.
- Rack/flow substructure handling.
- Experiment utilities routing.
- Common laboratory support equipment definition.

D. Performance Requirements and Conditions

1. Preflight

The PI, with the assurance of the TOT, will identify processing requirements for each of the functional objectives and

5.15 (continued)

define methods of meeting these requirements. Functional objectives which are totally associated with preflight activities such as experiment selection will be completed and documented during this period.

2. In-flight

Members of the TOT and the Flight Crew will evaluate aspects of payload processing during in-flight simulation and suggest changes or improvements.

The TOT will exercise care to document significant findings during this period.

3. Postflight

Through crew debriefing, system logs, and test operations logs, the participants will provide an evaluation of the payloads processing methods and suggested changes.

E. Environmental Requirements

None.

F. Hardware Requirements

None.

G. System Interface

None.

H. Data Support Requirements

- System logs
- Crew debriefing notes
- PI comments and suggestions

I. FDF Requirements

Flight Data File contents which have to do with the experiments or payloads activities associated with the functional objectives, such as experiments arrangement data, should be evaluated in accordance with this OTR.

5.15 (continued)

J. Test Operational Requirements

During the conduct of test wet runs and the actual 7-day simulation, crewmembers and the TOT should note any significant findings in appropriate logs or voice tapes.

K. Reporting Requirements

A final report will be required within two weeks of test completion.

L. Training Requirements

None.